APTD-70-1

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KANAWHA VALLEY AIR POLLUTION STUDY

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SEP 17 REC'D

ERRATA SHEET
FOR
APTD 70-1, KANAWHA VALLEY AIR POLLUTION STUDY

1. Page V, paragraph 7, "the Planning Commission Urban Renewal Authority" should be "the Planning Commission, the Urban Renewal Authority."

2. Page VI, paragraph 1, "the State Road (Planning District I Office and Kanawha County Offices)" should be "the State Road (Planning, District I Office and Kanawha County Offices)".

3. Page VI, paragraph 4, "Mr. Crofts farm" should be "Mr. Craft's farm".

4. Page IX, add "Appendix F, Description of Odor Testing . . . . F1".

5. Page 1-3. paragraph 1. "area wide" should be "area-wide".

6. Page 3-24, Table 3-11, Total Estimated Emissions, the Aldehyde column total should be "1,397" tons per year, not "1.397".

7. Page 4-1, paragraph 4, "at these stations" should be "at those stations".

8. Page 4-10, Figure 4-4, the "250 ug/m^3" and the "150ug/m^3" lines are approximately 25 ug/m^3 greater than the designated value. In legend of Table 4-4, New York State Objective "E" should be Objective "C."

9. Page 4-32, Table 4-20, Kanawha Valley Settled Particulate Values, the maximum value for Montgomery Heights should be "318" tons/square mile not "319".

10. Page 4-52, 53, 54, Figures 4-10, 11, 12, 13, Frequency Distribution of Sulfur Dioxide Concentrations Measured at Downtown Charleston, South Charleston, Nitro, Kanawha City and Marmet, the ordinate values or Sulfur Dioxide levels in parts per million should be divided by 100.

11. Page 4-63, paragraph 2, "The daily maximum and seasonal sulfur dioxide averages, Table 4-30" should be "The daily maximum values Table 4-30, the seasonal sulfur dioxide averages Table 4-39."

12. Page 4-106, Figure 4-51, Location of High Schools Participating in Student Odor Studies, delete one of the two "Jackson(s)" in "Stonewall Jackson".

13. Page 4-107, paragraph 2, "Appendix D" should be "Appendix F".

14. Page 5-12, paragraph 3, "proposed control regulations" should be "proposed control regulations".

15. Paee 5-26, paragraph 2, "potassium iodide colorimetric" should be "potassium iodide coulometric".

16. Page 5-35, paragraph 1, "estimated 103 miliion gallons of gasoline" should be "estimated 60.1 million gallons of gasoline".

KANAWHA VALLEY
AIR POLLUTION STUDY

Prepared by

Technical Staffs

of

National Air Pollution Control Administration

and

West Virginia Air Pollution Control Commission

Details of illustrations in
this document may be better
studied on microfiche

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Environmental Health Service
National Air Pollution Control Administration
Raleigh, North Carolina
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National Air Pollution Control Administration Publication No. APTD 70-1

FOREWORD

In response to requests from State Officials for assistance, the U.S. Public Health Service entered into an agreement with the West Virginia Air Pollution Control Commission to conduct a cooperative study of air pollution in the upper Kanawha Valley of West Virginia. The request was motivated by public expressions, continuing technical studies, subjective observations and previous air pollution studies, which indicated a need for air quality improvement. Effects noted as extremely adverse were reduced visibility, odors, fallout of particulate matter, and suspected health impairment. Several large chemical complexes and other industrial activities plus large amounts of coal consumed for process heat and power generation were indicated as major sources.

The purpose of the joint study was to determine the nature and extent of air pollution in the upper Kanawha Valley area, and to collect and assemble data and information as a basis for technical and official action needed to attain and conserve a desirable air quality. The joint study was conducted from August 1964 through December 1966 and included the following major activities:

1. Measurement of air quality.
2. Measurement and description of meteorological parameters.
3. Odor studies.
4. Collection and evaluation of existing information.
5. Pollutant emission inventory.
6. Study of materials deterioration.
7. Study of means and economics of pollution control.
8. Special studies on vegetation, health, public attitudes, and pollutants not routinely measured.

The results of studies of the first seven activities are incorporated throughout the body of the report. The studies in vegetation, health and attitudes listed as activity eight were conducted by members of the faculty at West Virginia University. Preliminary results of these studies were considered in developing Chapter V, the Air Resource Management Program.

The proposed recommendations in Chapter V do not affect the responsibility of the West Virginia Air Pollution Control Commission, however, in the development of acceptable air quality standards and implementation plans for any designated air quality control region, as required by the Federal Clean Air Act as amended.

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ACKNOWLEDGMENTS

The West Virginia Air Pollution Control Commission, the National Air Pollution Control Administration, and the Study Staff wish to acknowledge the cooperation and assistance of the following organizations and individuals who, in addition to those innumerable individuals, commercial, institutional, and industrial establishments and organizations not specifically listed, were involved in the conduct of the study. It should be noted that this is only a partial listing of those actively involved in the study and that it would be impossible to specifically thank everyone who participated in this effort.

The Joint Study Technical Committee for their invaluable advice and assistance in the conduct of the study, the review of data, the development of the air resource management program and resulting regulations, and the review of the study report.

The Citizens Air Pollution Control Council, it's Chairman and members.

The School Boards and Administrators of Kanawha, Fayette, and Putnam counties.

The Principals, Teachers and Service Staff of the following schools: Montgomery, Cedar Grove, East Bank, du Pont, Charleston, Stonewall Jackson, Sissonville, George Washington, South Charleston, Dunbar, St. Albans, Nitro, and Poca High Schools; Horace Mann and Nitro Junior High Schools; and Kimberly, Chesapeake, Ford, Glenwood, Marmet, Oakwood, Taft, Albans, Anne Baily, and Zogg O'Dell Elementary Schools.

The 1964-65 Students and Teachers of Montgomery, Cedar Grove, East Bank, Dupont, Charleston, Stonewall Jackson, Sissonville, George Washington, South Charleston, Dunbar, St. Albans, Nitro, and Poca High Schools who participated in the student odor survey.

The City of Charleston, especially the Fire Department, the Park and Recreation Commission, the Planning Commission Urban Renewal Authority, and the Sanitary Board and their respective staffs.

The Nitro and Glasgow Sanitary Commissions

Kanawha County, especially the Health Department, Planning and Zoning Commission, the Kanawha Air Port Manager and their respective staffs, and the County Library Board and library staff.

West Virginia University, West Virginia Institute of Technology, West Virginia State, and Morris Harvey College.

The West Virginia State Government, especially the Departments of Archives and History, Commerce (Industrial Development and Planning and Research Divisions), Health (Director, Industrial Hygiene Bureau, Sanitary Engineering Division, and State Hygiene Laboratory), Mines, Natural Resources (Water Resources Division), Public Safety (Company B Barracks, South Charleston), and Tax (Gasoline and Motor Carrier Road Tax): the State Road (Planning District I Office and Kanawha County Offices) and Library Commissioners; and the West Virginia Air (Kanawha County Airport) and Army National Guard (Falls View Armory).

The United States Government, especially the General Services Administration (Federal Building), the Environmental Science Services Administration (Kanawha Airport), the Post Office Department (Nitro and Belle Post Offices), the U. S. Army Reserve Training Center (South Charleston), and the Federal Aviation Agency and U.S. Army Corps of Engineers (London and Marmet Locks).

The E.I. du Pont de Nemours and Company, Inc., Belle; Union Carbide Corporation, South Charleston and Institute; FMC Corporation, South Charleston; and the Allied Chemical Corporation, Nitro; for meteorological data.

The Kroger Company, South Charleston; the Kanawha Valley Bank, the Teamsters' Union, and the True Temper Company, Charleston; Zim Supply Company, South Malden; Surface Chevrolet, Inc., Chelyon; and Mr. Crofts farm, Route 17, West of Nitro for providing sampling sites.

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KANAWHA VALLEY AIR POLLUTION STUDY

SECTION I.

INTRODUCTION

The first community in the Kanawha Valley, Fort Lee, was established in 1778 by Virginia Rangers under Colonel George Clendenin in what is now downtown Charleston, West Virginia.[1] In 1789, Kanawha County was created by an act of the Virginia Assembly, and in 1794, another act officially created the Town of Charleston. Daniel Boone represented the new county in the Virginia Assembly in 1791 while residing near present-day Charleston.

Valley industry began in 1795 with the manufacturing of salt from local brines. Salt brine is still a major raw material used by one of the present valley industries. In 1846, the salt production reached an all-time high of 80,600 tons.[2]

Coal oil and lamp oil were manufactured near Charleston in 1855. Iron manufacturing was a prominent industry during the period of 1798 through 1855.

Early transportation of these manufactured products was by pack animals, wagons, and rafts. With the addition of steamboats in 1816, steamboat packets shipped Kanawha Valley commodities as far west as the Mississippi and Missouri Rivers. In 1873, the Chesapeake and Ohio Railway reached Charleston and soon became the dominant means of transportation. The area is now serviced by four major railroads. Bulk shipment by barge, however, is still an important means of transportation.

The City of Charleston experienced slow growth until several manufacturing plants were established during the last quarter of the 19th century.[1,3] Since 1900, many of America's leading industrial firms have located plants in the Kanawha Valley, which by now is one of the most heavily industrialized areas in the United States. The valley is endowed with features that make this area particularly attractive to chemical companies — water for processing and as a means of inexpensive transportation of bulk products; ease of access to major markets; abundance of raw materials such as coal, natural gas, salt brine, and lumber; and low-cost power.

Future growth of the area will be enhanced by Charleston becoming the hub of three interstate highways, 64, 77, and 79.

AIR POLLUTION IN KANAWHA VALLEY

The first attempt to control air pollution was an ordinance enacted in 1928 by the City of Charleston; the ordinance encompassed fuel restrictions, inspection requirements, and penalties.[4] Another ordinance enacted in 1942 allows a smoke density of Ringelmann No. 3.[4] Local ordinances in numerous cities and towns in the valley prohibit open burning within corporate limits and require residents to use municipal or licensed collectors for waste disposal. These, plus local nuisance ordinances, are the only laws, regulations, and ordinances affecting air pollution in the Kanawha Valley other than the West Virginia Air Pollution Control Law enacted in 1961, and West Virginia Air Pollution Control Commission Regulations. The State Law is in effect throughout the entire State, with the exception of the City of Wheeling, which has the only local ordinance and control agency.

Control of air pollution in the Kanawha Valley is difficult because of the complexity of the industrial pollutants emitted and the varied processes employed by the chemical industries. The air pollution problem is also aggravated by topography and meteorology, which tend to limit dispersion and allow accumulation and persistence of pollutants.

PREVIOUS AIR POLLUTION STUDIES

Air pollution investigations of record conducted prior to this study were: (1) "Atmospheric Pollution Investigation — Metropolitan Area, Charleston, West Virginia,"[5] conducted by the West Virginia Department of Health, Bureau of Industrial Hygiene; (2)"A Study of Smoke and Air Pollution in the Kanawha Valley,"[6] was conducted in 1949 by the Coal Producers Committee for Smoke Abatement; and (3) "Atmospheric Pollution in the Great Kanawha Valley Area"[7] by West Virginia Department of Health, Bureau of Industrial Hygiene. In addition to these reports, both the West Virginia Air Pollution Control Commission and local industry have studied specific problems.

The first public air pollution study encompassed the area from Belle to St. Albans, and was initiated May 28, 1945, and terminated December 31, 1947. This survey was initiated by the Bureau "as a public service on behalf of the citizens of this area ...."[5] Measurements were made for settled dustfall — then called sootfall — and corrosion of steel plates. The number of dustfall stations ranged from 4 in 1945, which were operated on a weekly basis, to 12 in 1946, which were operated on a monthly basis. Wind data were obtained from the airport at Institute. Eleven corrosion stations in the valley extended from Montgomery to Poca with seven other stations established in downtown business districts of other West Virginia cities. Direct correlation between corrosion and dustfall was observed except for one station, Belle Locks. The study staff stated that the air pollution problems in the Kanawha Valley were serious enough to warrant consideration of plans for an overall atmospheric control program; that control programs and plans should be areawide and not for individual cities or communities; that the problem was an overall air pollution problem rather than a smoke problem; that future studies were needed and should include sampling of gases, vapors, and mists plus particulates; and that records should be continuous in order to evaluate effects of improvement and to obtain data for formulating regulations. The staff members also recommended that definite study goals be established so that additional studies would be more valuable.

The second study, initiated in October 1949 by a local mayor's group and conducted by the Coal Producers Committee for Smoke Abatement, extended from Cabin Creek to (and including) the City of Nitro. At the outset of the study, the valley's air pollution problems were recognized as being unique - that is, different from the then recognized problems found in Pittsburgh, Philadelphia, Cleveland, or Los Angeles. This study also recognized that the problems were valley-wide and were not confined to, nor could they be controlled by, one community. The scope of this study was limited to the inspection of those plants which were considered to have the greatest air pollution potential. Twenty-nine plants in the area were inspected and included all the major facilities with the exception of two plants, the electrometallurgical installation at Alloy and the Viscose plant at Nitro. The chemical plants surveyed were considered to be the major source of air pollutant emissions, followed by such sources as laundries, coal-burning locomotives, etc.

Included in the report were limited air quality data - principally dustfall and meteorological.

The Committee's recommendations were: (1) The development of a voluntary abatement program by industry with review of program effectiveness by a mayor's group; (2) the development of a regional air pollution program with the necessary control ordinances and regulations if the voluntary program was not effective; (3) continued sampling, principally of dustfall; (4) the establishment of a meteorological network; (5) the compilation of an emission inventory with suggestions on the control of reported emissions; (6) increased emphasis on the controlling of public and residential sources of pollution; (7) publicity for the efforts made to control air pollution; and (8) the employment by local industry of an outstanding research organization to study the more difficult control problems and to develop methods for abatement.

The third study, initiated in February 1950, and completed in August 1951, was funded by the Kanawha Valley Industries and the Department of Health. The industrial funds were collected by the Citizen's Anti-Air Pollution Committee. The study was undertaken because of intense public concern and recognition of this concern by public officials. Assisting the study staff were the Kettering Laboratory; University of Cincinnati,School of Medicine; and the U.S. Public Health Service, Division of Occupational Health. The objectives of the study as stated in the report[6] were:

1. "Establish factual information as to the air pollution problem of the valley.
2. "Determine the present or future needs of establishing an aggressive air pollution control program for the area.
3. "Compare the present particle-fall load of the valley to that of the period of a previous survey from June 1945 to December 1947."[5]

The study included an emission inventory, ambient air quality measurements, and a comparison of dustfall data with the dustfall results obtained during the June 1945 through December 1947 study.

The air quality network consisted of 28 dustfall stations and 9 high-volume filter sampling stations. The dustfall stations extended from Glen Ferris through Nitro. The gas sampling was conducted with mobile sampling units operating at 9 fixed sites and 10 variable sites either upwind or downwind of specified areas. The gaseous pollutants measured were sulfur dioxide, chlorine, aldehydes, ammonia, nitrogen oxides, fluorides, and hydrogen sulfide.

The emission inventory consisted of voluntarily reported particulate and gaseous emissions from: (1) Industrial combustion, (2) non-industrial combustion, and (3) industrial processes. Information for the emission inventory was not obtained from two of the major industrial plants, and mention was made of difficulty in obtaining emission information requested by the study staff. The inventory reported that total particulate emissions were approximately 500 tons per day and that the gaseous emissions were estimated to be 370 tons per day. The gaseous emissions consisted mainly of sulfur oxides and other sulfur compounds. Unreported process emissions were thought to be significant.

Dustfall results from stations included in both the 1945-47 and 1950-51 studies were similar. Dustfall results in seven study stations averaged above 100 tons per square mile per month. Overall results also indicated that the atmospheric pollutants were mainly from the industrial plants and that the higher air pollution levels usually occurred downwind from these industrial plants. The sulfur dioxide, ammonia, and particulate levels were normally greater during the late night and early morning hours, and these levels generally increased with the occurrence of fog or smog in the valley. The study also indicated that pollutants emitted from the Glen Ferris-Alloy area were transported nearly 30 miles downriver into the Charleston and South Charleston areas. Meteorological observations at one station indicated air movements downriver in the early morning and upriver later in the day.

Unpleasant odors were recorded when observed, but no formal odor studies were conducted. Although the report indicated that annoying odors were a problem, these odors were not thoroughly studied because analytical means of identification were not available except in a few cases. Some of the industries reported data on emission of certain potentially malodorous materials.

Results of the study indicated that air pollution in the Kanawha Valley was severe enough that the studies should be continued and that they should make recommendations for aggressive control measures where the need is indicated. The study — the first in a major chemical-industrial area — was beset with difficulties; it did, however, contribute useful information for later studies and development. Some control equipment, primarily for control of flyash, was installed by certain industries in the valley after completion of the study.

PRESENT AIR POLLUTION STUDY

Study Area

The Kanawha River, formed by the juncture of the New River and the Gauley River at Gauley Bridge, flows generally northwestward through a winding valley to join the Ohio River at Point Pleasant. That portion of the valley designated as the "study area" extends from Gauley Bridge to just below Nitro, a distance of approximately 52 miles. The valley begins with a width of about 0.5 mile, widens gradually to 1.0 mile at Charleston and 1.3 miles at Institute, and narrows again to 1.0 mile at Nitro. The Kanawha River begins at an elevation of about 600 feet at Gauley Bridge and descends through a series of navigation dams and locks to 556 feet at Nitro. Hills rise 800-1000 feet above the valley floor near Gauley Bridge, 400-600 feet at Belle, 300-400 feet at Charleston, and 200-400 feet at Nitro. Two major tributaries enter the Kanawha River in this area, the Elk River from the north at Charleston, and the Coal River from the south at St. Albans. Most of the study area is in Kanawha County, but small parts of Fayette County to the east and Putnam County to the west are included. The population of the study area is about 220,000. Included in the area are the State capital, Charleston (86,000), South Charleston (19,180), St. Alban (15,103), Dunbar (11,006), Nitro (6,894), and Montgomery (3,000) plus several small communities and unincorporated areas.[8] The major industries are concentrated in the valley from South Charleston to Nitro, with large isolated industrial plants located upriver at Kanawha City, Belle, and Alloy. A map of the study area is shown in Figure 1-1.

Initiation of Study

The three previously discussed air pollution studies, continuing industrial and governmental technical studies, and public expressions of concern for more than a decade, plus the existing activities of the West Virginia Air Pollution Control Commission (APCC) and local industry, indicate an awareness on the part of residents of the study area of an undesirable air environment.

The West Virginia Legislature passed a Statewide air pollution control statute[9] forming the West Virginia Air Pollution Control Commission in July 1961. During Fiscal Year 1963, the Commission first received an appropriation of $20,000, which was increased to $33,000 in Fiscal Year 1964. The Commission staff included the Director, one chemical engineer, a technician, and a secretary. The staff conducted some studies of air quality and made initial surveys of some air pollutants. The Commission soon sought additional resources primarily to help implement more rapid progress in resolving the complex problems of the Kanawha Valley. As a result, assistance from the Division of Air Pollution of the Public Health Service was requested, and the West Virginia Air Pollution Control Commission entered into an agreement (see Appendix A) with the Public Health Service to conduct a cooperative study to delineate the nature and extent of the air pollution problem in the study area.

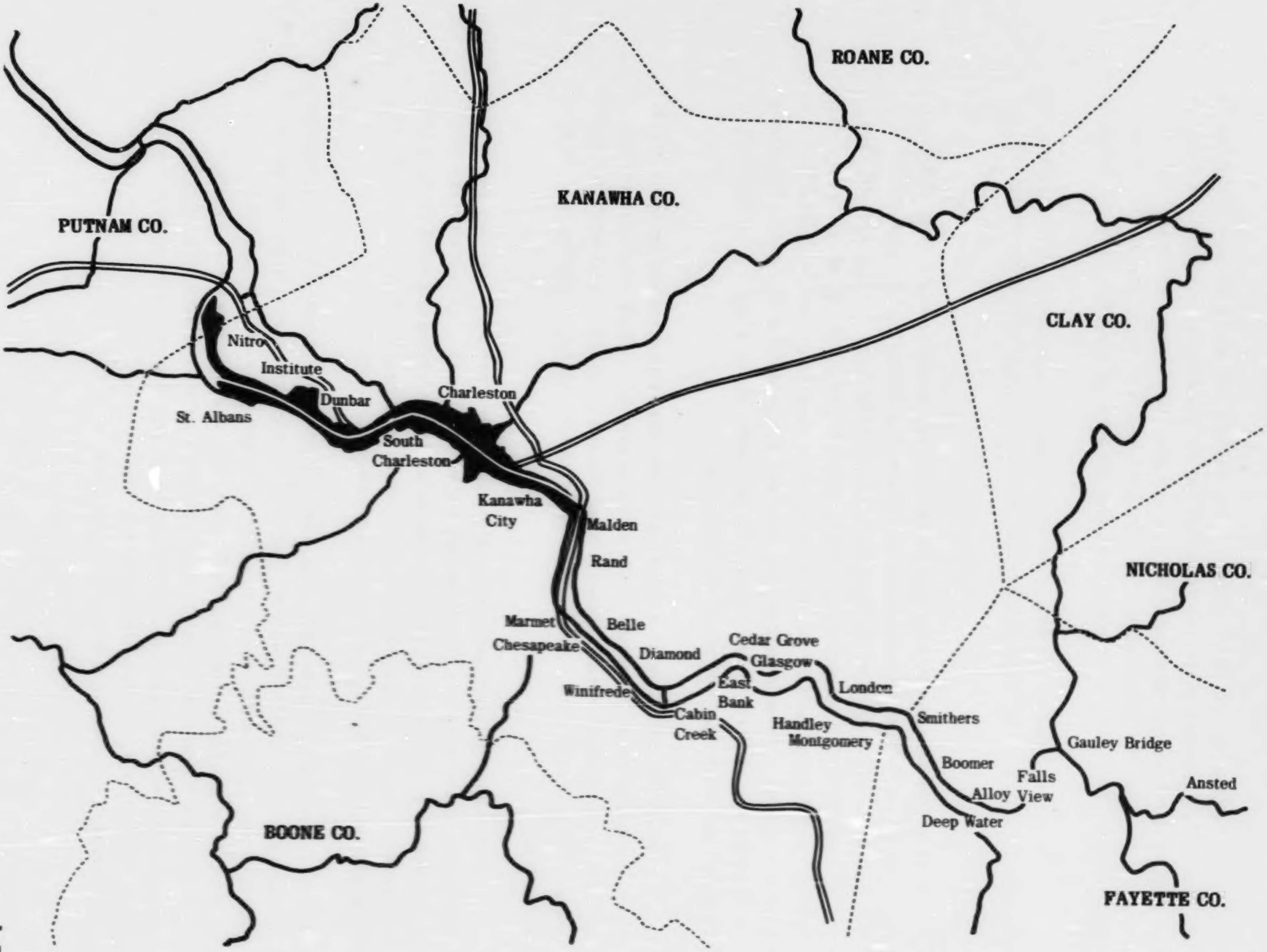
ROANE CO.
KANAWHA CO.
PUTNAM CO.
CLAY CO.
NICHOLAS CO.
BOONE CO.
FAYETTE CO.
Nitro
Institute
Dunbar
St. Albans
Charleston
South Charleston
Kanawha City
Malden
Rand
Belle
Marmet
Chesapeake
Diamond
Cedar Grove
Glasgow
East Bank
Winifrede
Cabin Creek
London
Handley
Montgomery
Smithers
Boomer
Alloy
Falls View
Deep Water
Gauley Bridge
Ansted

Figure 1-1. Kanawha Valley air pollution study area.

Purpose and Scope of Study

The purpose of the joint study was to evaluate the air pollution situation in the industrialized portion of the Kanawha River Valley and to assist in the development of an air resource management program for the study area. The study was also expected to help in the development of personnel and facilities for air pollution control work, both within the study area and the rest of the State of West Virginia.

The Kanawha Valley Air Pollution Study began in Charleston, West Virginia, on August 5, 1964. The study was divided into the various activities discussed below.

Air Quality Studies — Continuous routine ambient air sampling stations were set up at 14 locations. These stations were to measure the following contaminants: (1) Dustfall, (2) suspended particulate, (3) soiling index, (4) sulfation rate, and (5) deterioration of materials. There were 13 lead-peroxide candles and dustfall-monitoring stations in addition to those located at the 14 routine air monitoring stations. After data had been obtained for a minimum of 1 year, the number of stations was reduced to 14. These stations were run on a continuing basis to provide data for a study of metal deterioration.

The Public Health Service mobile air-sampling laboratory was operated for 1-month periods at seven locations, on a rotating schedule. This mobile laboratory was equipped with continuous automatic sampling and recording instruments for measurement of sulfur dioxide, carbon monoxide, oxidants, nitrogen dioxide, and total hydrocarbons.

After data on other pollutants emitted to the atmosphere (besides the common pollutants measured by the foregoing routine methods) were attained from the emission inventory, some special studies were initiated to evaluate concentrations of selected pollutants in the neighborhood of known or suspected sources. These studies involved a variety of sampling and analytical techniques.

Air Pollutant Emission Inventory — An inventory of air pollutant emissions from all sources was made. Major industrial plants were asked to examine their operations and to report, by questionnaire, on major pollutant emissions as accurately and completely as possible. An engineering appraisal was made of each major coal-burning plant to provide information on potential pollutant emissions, existing emission control practices, and ramifications of possible emission control requirements. Discussions between plant personnel and the study staff were held to make the inventory as complete and useful as possible.

Data on pollutant emissions from small industrial plants, commerical establishments, transportation, homes, and other sources were gathered by using questionnaires, tracing fuels from suppliers and transporters to users, and studying data gathered previously by others.

Meteorological Studies — Meteorological studies were made to describe the dispersion and transport of pollutants, to aid in interpretation of air quality and other data, and to provide information on the total capacity of the air of the valley to absorb and disperse pollutants so that emission regulations could be designed to provide the necessary pollutant-emission reduction needed to achieve desired air quality now and in the future.

Wind speed and direction instruments were operated at 14 locations, including 5 stations operated by industrial firms and 1 operated by the U.S. Weather Bureau at the Kanawha Airport. Temperature measurements were made at 20 stations (including 8 river temperature stations), and relative humidity was measured at 12 locations. Special intensive observations were made during 1 week of each season of a year with the exception of a 2-week study during the Fall of 1965. These observations were to provide a more detailed portrayal of meteorological conditions than could be obtained from the routinely collected data. These special measurements included vertical temperature soundings with a tethersonde unit at 2-hour intervals up to 1,000 feet above the valley floor. Pilot balloons were released at 2-hour intervals to determine wind speed and direction at elevations up to 5,000 feet above the surface. Tetroons were released at dawn and near sunset to plot trajectories of air parcel movement at a level of about 200 feet above the surface.

Odor Studies — Prevalence of odors in the area was determined by high school students at their homes who noted in the morning, afternoon, and evening, the presence or absence of odors and, if present, the odor characteristics. These observations indicated the frequency of occurrence and geographic distribution of odors. Students were given tests to determine their odor-sensing acuity. Observations were made during 3-week periods in the fall and spring seasons. Staff personnel also made odor and meteorological observations in the neighborhood of probable odor sources. Correlations of these observations with wind direction and information on source operating conditions were made to determine the source and cause of odorous pollutants.

Vegetation Damage Studies — A study, financed by the Public Health Service, was conducted by West Virginia University to try to determine whether certain species of natural vegetation have ceased to exist because of their sensitivity to air pollutants. Comparisons of the species present in a polluted area with those in similar, unpolluted areas nearby were made. Field inspections of plant plots placed throughout the study area and natural vegetation in the vicinity of major pollution sources were also conducted to see whether any identifiable acute injury occurred and to estimate for each occurrence as to the concentration, duration, and identity of the causative pollutant(s).

Materials Deterioration — Studies were conducted by the Field Studies Branch, Division of Air Pollution, U.S. Public Health Service, to determine the effects of air pollutants on certain materials. The rate of corrosion of steel and zinc, and deterioration of Nylon was measured at 12 stations, and fading of dyed fabrics at 11 locations. Deterioration of cotton was measured at 2 of those stations. The study staff hoped that these tests would provide some data on economic damage due to air pollution and an insight into the identity of pollutants causing damage.

Collection and Evaluation of Existing Information — Existing information and data relating directly or indirectly to the air pollution situation in the valley, such as the three previously discussed air pollution studies, plus census, planning, traffic, area economic studies and surveys, and other sources of information were collected and analyzed.

Means and Economics of Pollution Control — Information pertaining to the cost of control equipment and operating costs as well as the costs of process equipment or fuel changes involved in achieving a given degree of control of pollutant emissions was available on a limited basis with respect to fuel-burning operations and was used in the design of Regulation II, which controlled particulate air pollution from boiler furnaces.[10] In a complex chemical plant, however, such data are difficult to obtain.

Design of an Air Resource Management Program — On the basis of all data collected in this study and other pertinent information, an air resource management program was designed.

Recommendations resulting from this project were developed in collaboration with all available groups. The West Virginia Air Pollution Control Commission will then consider the recommendations and, as empowered by State Law, promulgate such rules and regulations as the Commission may find appropriate.[9]

Health Study — Knowledge of the possible effects of air pollution on health, and investigations to define these possible effects in the Kanawha Valley were desirable, but the cooperating agencies did not have the funds and personnel available to conduct such studies at that time. Funds were provided, however, by the Field Studies Branch, Division of Air Pollution, U.S. Public Health Service, to research a potential method of conducting a study of the effects of air pollution on health. This research was conducted under a Public Health Service Contract by the West Virginia University Medical School.

Public Attitudes — Public attitudes and opinions about air pollution were of concern since air resource management is not only a technical and economic consideration related to possible health effects, property damage, and nuisance, but also a matter of sociology, aesthetics, and community purpose. There are also some indications that air pollution has psychological implications. Here again, however, the cooperating agencies did not have resources available to apply to studies of these matters. Again funds were provided by the Field Studies Branch, Division of Air Pollution, U. S. Public Health Service, in a research grant to West Virginia University to conduct a study of the effects of air pollution on public attitudes.

Study Organization and Program

The two cooperating agencies, the West Virginia Air Pollution Control Commission and the U. S. Department of Health, Education, and Welfare, Public Health Service, Division of Air Pollution were responsible for doing the work of the study. These agencies were responsible for policy decisions, approval of finished reports, and support of project operations.

To administer, control, and coordinate the study staff, the Joint Study Executive Council was established. The Joint Study Technical Committee was formed to provide advice to the cooperating agencies in conducting the study. The Citizen's Air Pollution Council was organized to provide a means of informing the community of study progress and an opportunity to receive suggestions from citizens in the study area.

The Joint Study Executive Council consisted of two representatives from each of the cooperating agencies and was responsible for the administration of the project. The Public Health Service representatives were the Regional Program Director for Air Pollution Activities, Region III; and the Chief, Technical Studies Section, Technical Assistance Branch, Division of Air Pollution. The West Virginia APCC representatives were the Chairman and the Executive Director. The Executive Director of the Commission was designated as the Project Director.

The Joint Study Technical Committee was responsible for advising the Joint Study Executive Council and the cooperating agencies on the objectives of the project, conduct of the work, and on periodic and final reports. The Joint Study Executive Council prepared the agenda and information documents for use by the Joint Study Technical Committee. The Committee was composed of representatives from the West Virginia APCC; the Kanawha Valley Air Pollution Technical Advisory Council; West Virginia University; West Virginia Institute of Technology; the Kanawha Valley Industries; and the U.S. Department of Health, Education, and Welfare, Public Health Service, Division of Air Pollution.

The third study organization was the Citizen's Air Pollution Council (Appendix A). The Council was composed of representatives of various organizations and citizens having an interest in conservation of the air resources of the Kanawha Valley. The Council was originally organized by the Joint Study Executive Council and was formed by invitation. The purposes of the Council were to provide a means whereby broad segments of the community were informed on the progress of the study, and to provide the citizens with opportunities to make suggestions to the cooperating agencies concerning the conduct of the study, findings, and other pertinent subjects.

The work program followed the general chronological order listed below:

August 1964 - Formal signing of work agreement.
Initiation of mobile laboratory sampling.
Expansion of high-volume sampler network and initiation of strip tape sampler network.
September 1964 - High-volume sampler network in full operation (14 stations).
Emission inventory started.
October 1964 - Strip tape sampler network in full operation (14 stations).
Initiation of deterioration study.
Initiation of meteorological network (wind and hygrothermograph stations).
November 1964 - Initiation of dustfall and lead peroxide network (14 stations).
First student odor survey.
December 1964 - Dustfall and lead peroxide network in full operation (27 stations).
January 1965 - Hygrothermograph network in full operation (11 stations).
First week of intensive meteorological study.
February 1965 - Meteorological network in full operation (excluding the station at London Locks) (17 stations).
April 1965 - Second student odor survey.
May 1965 - Second week of intensive meteorological study.

June 1965 - Initiation of vegetation study.
July 1965 - Third week of intensive meteorological study.
August 1965 - Particulate emission inventory completed.
Started drafting Regulation II, Control of Particulate Emissions from Fuel Combustion.
October 1965 - Draft of Regulation II completed and forwarded to West Virginia Air Pollution Control Commission.
October and November 1965 - Fourth period of intensive meteorological studies.
December 1965 - Public Hearing on Regulation II.
Air quality network data cutoff.
January 1966 - Mobile laboratory sampling data cutoff.
February 1966 - Regulation II adopted by West Virginia Air Pollution Control Commission.
March 1966 - Meteorological network data cutoff with exception of London Locks wind station.
April 1966 - Regulation II became effective.
Started odor patrols.
May 1966 - London Locks wind station data cutoff.
June 1966 - Drafted odor regulation.
October 1966 - Completed gaseous emission inventory.
December 1966 - Odor regulation completed and forwarded to West Virginia Air Pollution Control Commission.
June 1967 - Public hearing on Regulation IV, Control of Objectionable Odors
July 1967 - Draft of Chapters I, II, III, and IV of study report completed.
August 1967 - Regulation IV approved by West Virginia Air Pollution Control Commission.
October 1967 - Regulation IV became effective.

SPECIAL STUDIES

Studies were conducted in each of the eight major activities and the results of the first seven studies are incorporated throughout the body of this report. Separate published and unpublished reports record the results of portions of studies related to part eight but are not included in their entirety.[11-15] These "studies in vegetation, health, and attitudes" were conducted by members of the faculty at West Virginia University, supported by either a Federal grant or contract. Preliminary results were considered in developing Section 5, the Air Resource Management Program. The last item in eight, "Pollution not routinely measured," was investigated by members of the staff of the West Virginia Air Pollution Control Commission and the Division of Air Pollution of the Public Health Service. These results are reported in Section IV.

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SECTION II.
METEOROLOGY

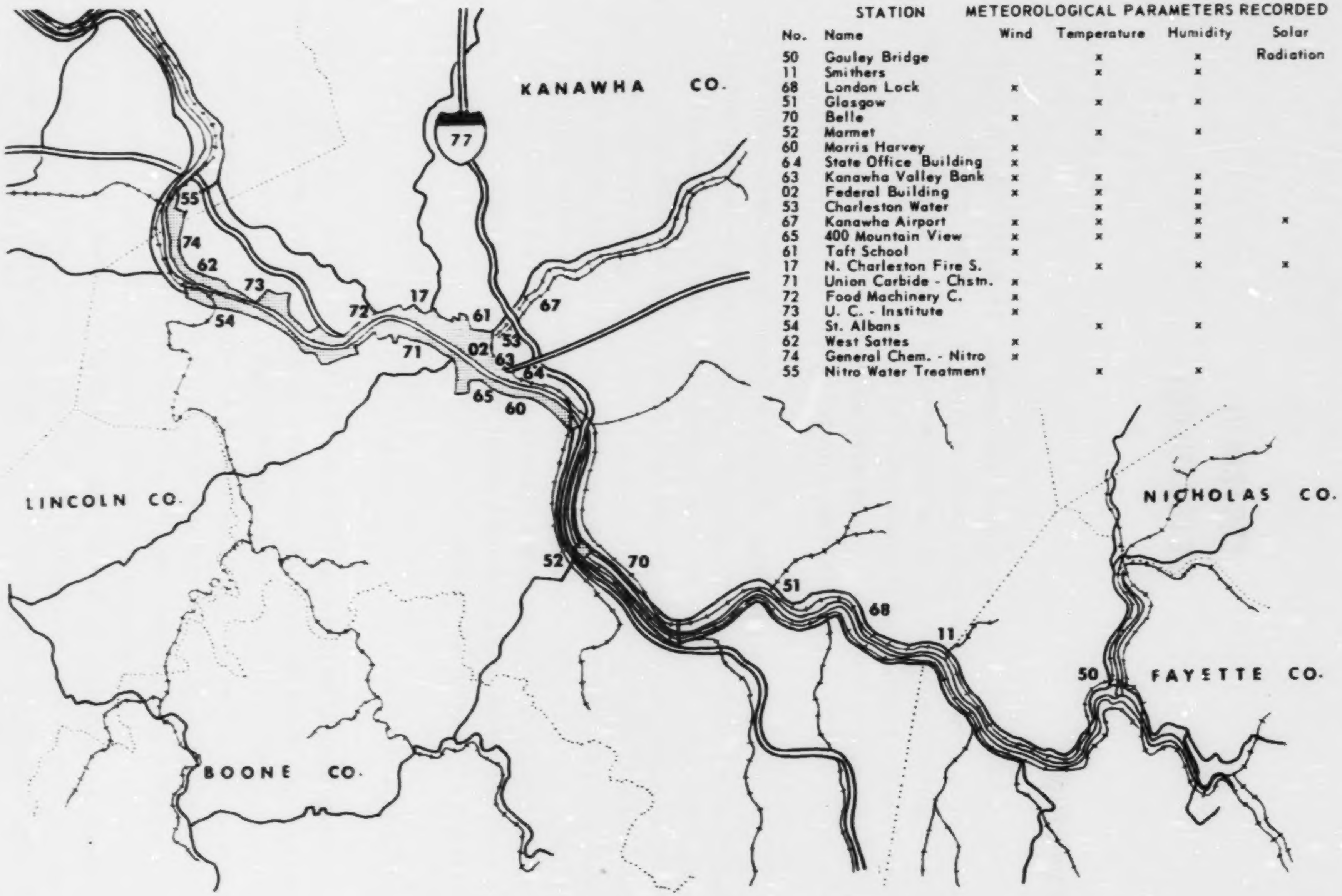
INTRODUCTION

The Kanawha Valley Air Pollution Study Agreement of August 1964 included provision for a major meteorological study, a distinct departure from the previous studies of 1945-47 and 1950-51. The meteorological phase of the overall study was included in order to determine the representativeness of the aerometric data obtained, to relate aerometric data to meteorological parameters, and to provide a basis for establishing permissible emission rates.

In addition to permanent meteorological equipment in the area, supplementary installations were made and maintained over a period essentially between September 1964 and March 1966. An effort was made to secure at least a full year of record by extending the operation in specific instances. A full-time meteorologist was in residence from October 1964 through July 1966. The first part of this chapter describes those meteorological parameters of special interest in the current study while the latter part discusses the data and presents selected examples. For ready reference, site locations and instrumentation are indicated on Figure 2-1. Details of instruments used, instrument exposures, and complete meteorological data gathered are included in Appendix B.

Meteorological Stations

Meteorological stations supplying data for this study fall into three major categories: (1) Permanent stations established by the U. S. Weather Bureau, including the first-order station at the airport and three cooperative climatological stations in the valley; (2) industrially owned and operated wind-speed and direction recorders from which data were available; (3) and specially installed meteorological stations of two types, one with wind-speed and direction recording equipment, the other with temperature and humidity recorders. Wind-speed and direction instruments were operated at 14 locations, including five stations operated by industrial firms and the one operated by the U. S. Weather Bureau at Kanawha Airport. Temperature, and frequently humidity, was recorded at 20 stations including



KANAWHA CO.
LINCOLN CO.
BOONE CO.
NICHOLAS CO.
FAYETTE CO.
77
55
74
62
73
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72
17
71
61
02
53
63
64
65
60
67
52
70
51
68
11
50

STATION		METEOROLOGICAL PARAMETERS RECORDED			
No.	Name	Wind	Temperature	Humidity	Solar Radiation
50	Gouley Bridge		x	x	
11	Smithers		x	x	
68	London Lock	x			
51	Glasgow		x	x	
70	Belle	x			
52	Marmet		x	x	
60	Morris Harvey	x			
64	State Office Building	x			
63	Kanawha Valley Bank	x	x	x	
02	Federal Building	x	x	x	
53	Charleston Water		x	x	
67	Kanawha Airport	x	x	x	x
65	400 Mountain View	x	x	x	
61	Taft School	x			
17	N. Charleston Fire S.		x	x	x
71	Union Carbide - Chstn.	x			
72	Food Machinery C.	x			
73	U. C. - Institute	x			
54	St. Albans		x	x	
62	West Sattes	x			
74	General Chem. - Nitro	x			
55	Nitro Water Treatment		x	x	

Figure 2-1. Meteorological instrumentation in the Kanawha Valley.

eight river temperature stations. Special intensive observations were made from three different locations. Most of the above sites were assigned numbers within a larger air-monitoring-network system.

Special Meteorological Studies

In order to determine the details of the atmospheric circulations in the valley, more information was needed than could be obtained from the fixed network of meteorological stations. This information includes vertical temperature distribution, the variations of wind speed and direction with height, and wind-flow patterns. To obtain data of this type a meteorological tower would have been useful for vertical data, and a very dense network of wind instruments would have been needed for flow patterns. A sufficiently tall meteorological tower would have involved great expense, and the amount of data programmed had already presented a serious problem in data reduction and analysis. For these reasons, the staff members decided to make special seasonal studies.

For these special seasonal studies, three types of equipment were used. A tethersonde[1] was used to obtain vertical temperature gradients up to 1,000 feet, and pilot ballon (pibal) observations were made to measure wind speed and direction in successive layers of air up to several thousand feet. Wind data was augmented by tracking a "tetroon" visually as this device floated with the wind at essentially a constant level. Details of equipment and a description of the intensive study program are included in Appendix B.

The staff members believed that this series of wind and temperature measurements through the first few thousand feet above the valley floor could be related to studies carried out by others[2,3] in other valleys and that the air movement within the Kanawha Valley could be thereby determined.

GENERAL METEOROLOGICAL PARAMETERS

The rate at which atmospheric pollutants are carried away from a source, the rate at which pollutants are diluted to acceptable or allowable concentrations, the effect of pollutants upon receptors, and the eventual removal of the pollutants from the atmosphere are dependent upon several meteorological parameters. Some of these parameters act directly and some in concert with the others. A number of these parameters can be measured directly; others must be derived. Though the effects of these parameters cannot be considered separately in practice, the parameters can be discussed separately. Those of major interest in air pollution considerations and their general applications are described below. The specific use of these parameters in relation to the data gathered will be discussed later in the report.

Wind

The meteorological element wind has both direction and speed. The principal effect of wind direction is readily apparent. If the wind is blowing from a source to a receptor, the receptor can expect to be effected by whatever effluent the source is emitting. When the wind direction changes sufficiently, the receptor will no longer be effected. Short-period variations in wind direction have the effect of reducing the average concentration of pollutants effecting a receptor located generally downwind from a source during the observation, since the plume reaches the receptor only intermittently. These short-period variations may last only a few seconds or much longer. The wind may shift only a few degrees of azimuth or may swing completely around the compass. The changes in direction of the winds are the result of eddies of many sizes superimposed on the general wind flow. These eddies are especially marked near the ground and are produced by wind flow over and around obstacles. Longer variations in wind direction are produced by eddies of larger scale, up to circulation systems thousands of miles across. Variations in wind direction are readily seen when watching a wind vane oscillate.

An analogue-type wind record showing characteristic directional variability is included as Figure 2-2. In the figure, a protracted wind shift into the west is apparent at 2015. After the shift, the wind settled into a more westerly direction with an increased gustiness.

The effect of wind speed is not quite so readily apparent, but can be understood easily. Effluents are transported from their source and diluted to lower concentrations in direct proportion to the wind speed. Thus, a stack discharging smoke at a constant rate will cause only half the concentration of effluents in the downwind area if the speed of the wind passing the stack doubles.

The short-period eddies described above are also apparent in wind speed. An eddy that results in a sudden brief rush of wind is referred to as a "gust." Gusts are normally apparent on analog wind records as temporary changes in direction accompanied by abrupt short-period changes in speed. Figure 2-3 is the companion speed trace to Figure 2-2. Note the minimum in speed which accompanied the wind shift at 2015. Gusty winds generally occur when the air is being rapidly heated, as, for example, on a bright sunny day. Strong winds above the surface also add to the probability of gusty surface winds on such days. During daytime the wind in a valley is expected to be of the order of one-half the speed that would be present under the same meteorological conditions over a wide flat plain, while at night under inversion conditions the speed (and direction) may be entirely unrelated to the general wind outside the valley.

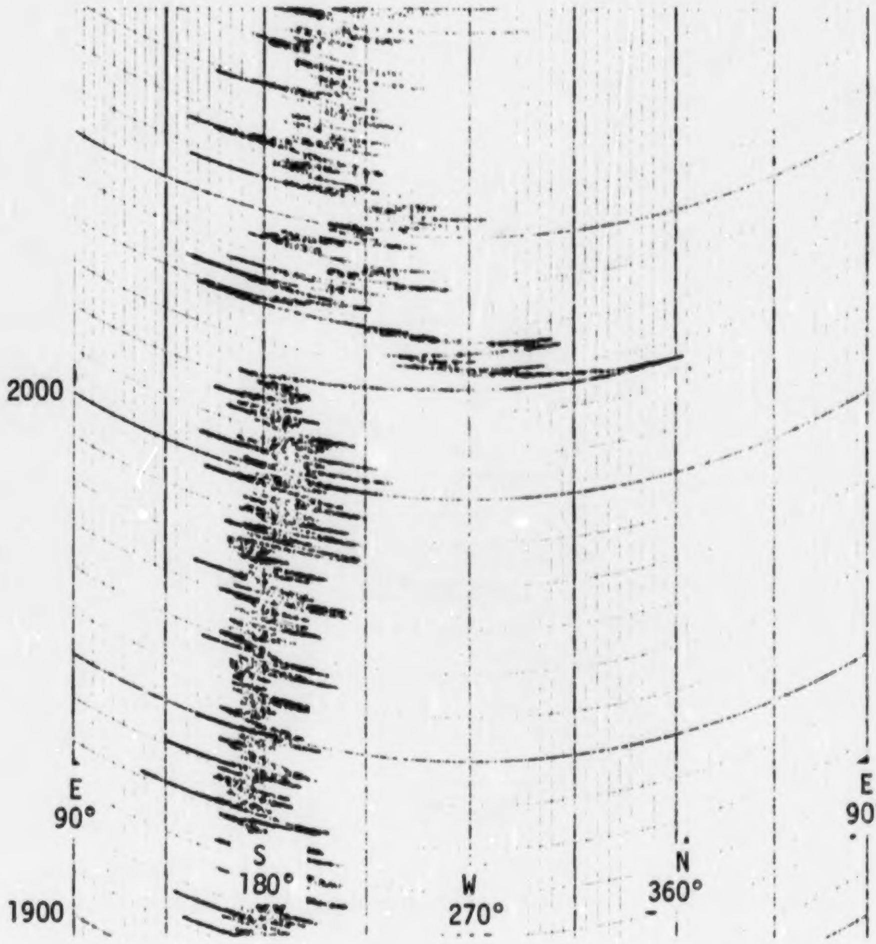


Figure 2-2. Wind direction trace showing normal direction variability with one protracted change into west at 2015.

Sunshine

The earth receives heat from the sun as shunshine, while cloud layers act as an insulating blanket. By day, much of the sun's radiation that strikes clouds is reflected back into outer space and is lost to the earth so that slower surface

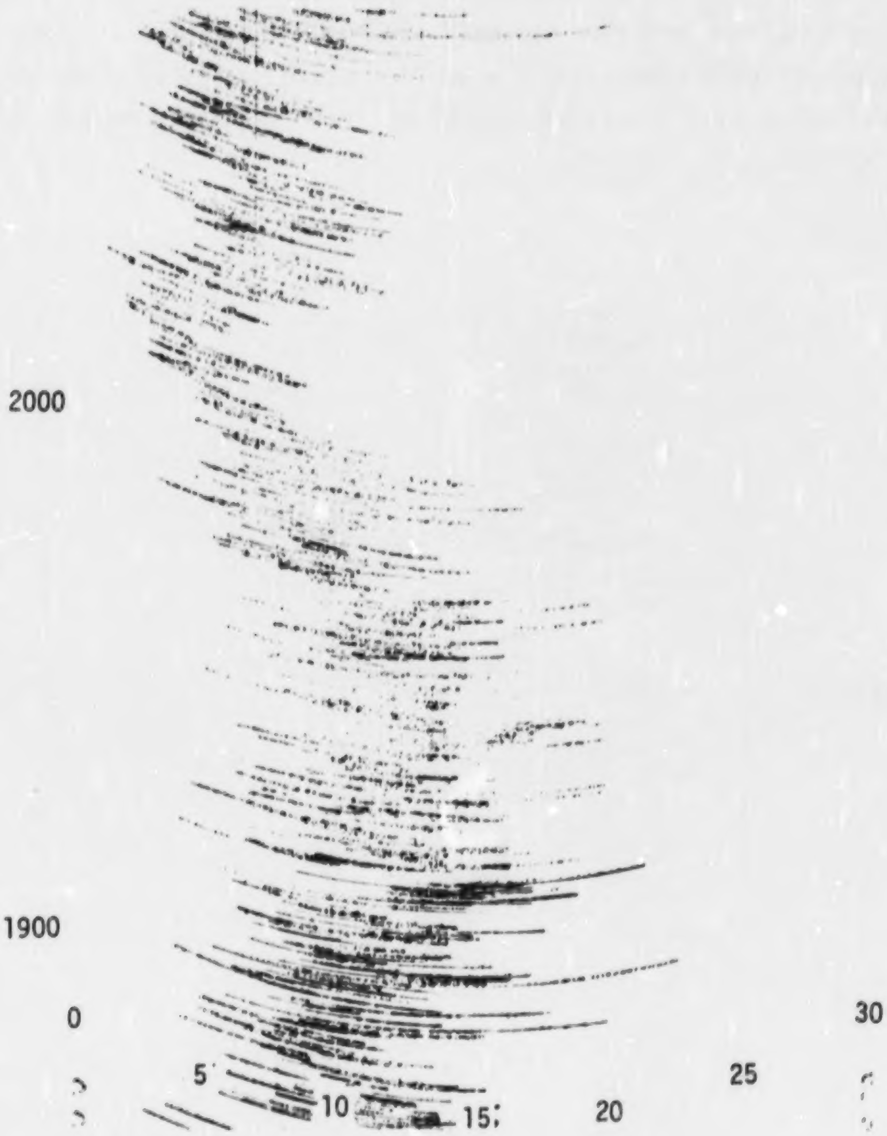


Figure 2-3. Characteristic analogue wind speed trace.

heating is experienced beneath clouds than in areas of bright sunshine. By night, much of the earth's radiation striking clouds is reflected back to the earth so that less cooling takes place than would occur without clouds. Even on cloudy nights an inversion is normal, but it tends to be less pronounced. When clouds persist the following day, the dissipation of an inversion is delayed because of slow surface heating.

In addition to heating the earth and thereby causing atmospheric circulation, sunlight promotes a group of photochemical reactions among air pollutants, mostly those emitted by automobiles. Sunlight can also be used to measure, indirectly, the quantity of particulate material in the atmosphere.[4] Duration of sunshine (time during which the sun produces a shadow) is not always recorded by weather observing stations, but may be approximated by using statistics on average daily cloudiness. Intensity of sunshine is recorded by selected weather bureau stations and research facilities by means of a variety of instruments. In the present study, two recording pyrheliometers were used.

Temperature

Temperature and atmospheric stability are closely related to sunshine. Temperature is a measure of the degree of heat and varies directly with the amount of radiation absorbed by a parcel of air.

The use of heating fuels by, and consequent stack emissions from home and industrial space-heating units, increase rapidly as the outside temperature falls. A "degree-day" has been defined as the 24-hour mean temperature subtracted from 65° F with negative values being recorded as zero. Large fuel users and fuel delivery services can accurately measure and program their activities by these heating degree-day values. Air polluting stack emissions from fuel combustion for space heating can also be estimated from the degree-day values.

Stability

Stability is resistance to change. In the atmosphere, stability is usually measured by the change of temperature with height or lapse rate. Because of the interaction of pressure and temperature, a parcel of air ascending through the atmosphere will undergo an increase in volume and a decrease in temperature. If the parcel of air is insulated from its surroundings, or is moved quickly enough to prevent exchange of heat with the surrounding air, the temperature will change at the rate of 5.4° F for each 1,000 foot change in elevation. This rate of temperature change with altitude is termed the "adiabatic lapse rate." If, when released at a new position, the air parcel is warmer than the surrounding air (and less dense), the parcel will rise due to the density differential; similarly, a cooler air parcel will sink. If this tendency to rise or sink returns the parcel to the level of origin the atmosphere is stable; but if the tendency is to move the parcel farther from the level of origin, the atmosphere is unstable.

The several stability categories used in air pollution work are defined below in the order of decreasing stability.

1. Inversion - Temperature increases with height.
2. Isothermal - Temperature invariant with height.
3. Weak lapse rate - Temperature decreases with height at a rate less than the dry adiabatic rate.
4. Neutral or dry adiabatic - Temperature decreases at a rate of 5.4° F per 1,000 feet of elevation.
5. Superadiabatic, or strong lapse - Temperature decreases with height at a rate greater than the dry adiabatic rate. This is possible since mixing does not occur instantaneously and air exhibits some properties attributable to momentum and viscosity.

The broad term "stable" covers categories 1, 2, and 3 above, while "unstable" usually refers to a strong lapse condition. The effect of these stability classes on a smoke plume is shown in Figure 2-4, an idealized sketch.

Variations in stability are produced by several mechanisms, but only two are of significance here. Near the earth's surface temperature changes in the air are principally effected by exchange of heat between the air and the surface. During the day, the earth's surface receives thermal energy by radiation from the sun and during the night, gives off thermal energy by radiation and conduction. The usual result is daytime warming and nighttime cooling of the surface and of the lower atmosphere. This process usually produces a diurnal variation in stability, ideally from very stable before sunrise to unstable in the afternoon. Seasonal variations usually occur with changes in solar elevation and length of day and night. Figure 2-5 shows this daily variation averaged by calendar month for a layer of air above a city.

Radiation effects are greatly influenced by variations in cloudiness, and are nullified, so far as stability is concerned, by strong winds.

Turbulent mixing is produced by wind blowing over uneven terrain. The surface-induced mechanical turbulence under a strong wind condition results in a well-mixed adiabatic layer of air. Under very light wind conditions, radiation effects determine the temperature profile so that superadiabatic conditions may be found during periods of strong heating with an inversion beginning to form at the lowest level soon after shadows cover the area near sunset. The inversion usually becomes deeper and more intense thereafter until morning.

Stable air inhibits the creation of eddies and thus the diffusion of air pollutants, whereas an unstable condition supports the creation of eddies and accelerates the diffusion of air pollutants.

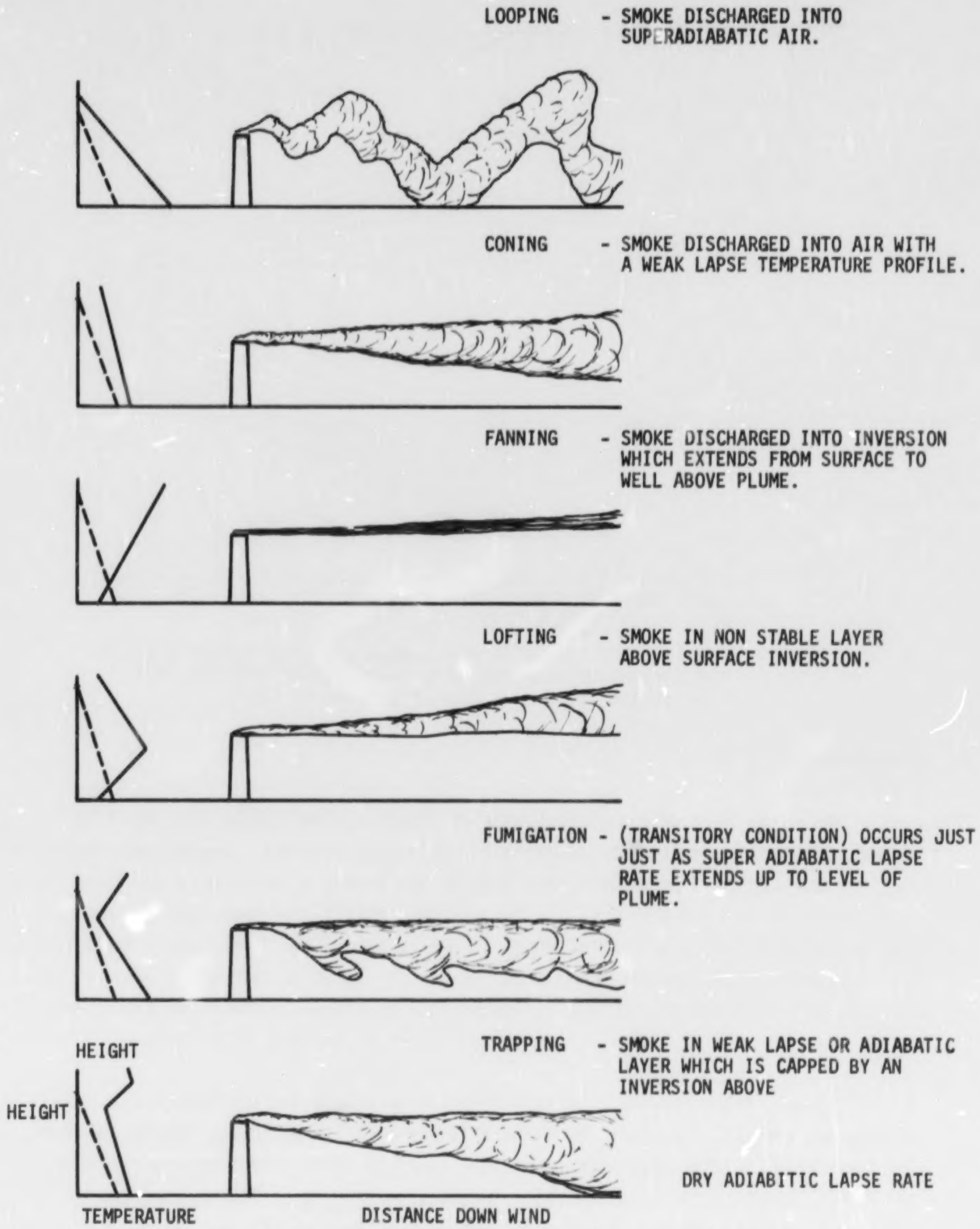

LOOPING - SMOKE DISCHARGED INTO SUPERADIABATIC AIR.
CONING - SMOKE DISCHARGED INTO AIR WITH A WEAK LAPSE TEMPERATURE PROFILE.
FANNING - SMOKE DISCHARGED INTO INVERSION WHICH EXTENDS FROM SURFACE TO WELL ABOVE PLUME.
LOFTING - SMOKE IN NON STABLE LAYER ABOVE SURFACE INVERSION.
FUMIGATION - (TRANSITORY CONDITION) OCCURS JUST JUST AS SUPER ADIABATIC LAPSE RATE EXTENDS UP TO LEVEL OF PLUME.
TRAPPING - SMOKE IN WEAK LAPSE OR ADIABATIC LAYER WHICH IS CAPPED BY AN INVERSION ABOVE
HEIGHT
HEIGHT
DRY ADIABITIC LAPSE RATE
TEMPERATURE
DISTANCE DOWN WIND

Figure 2-4. Effects of stability variations on a plume.

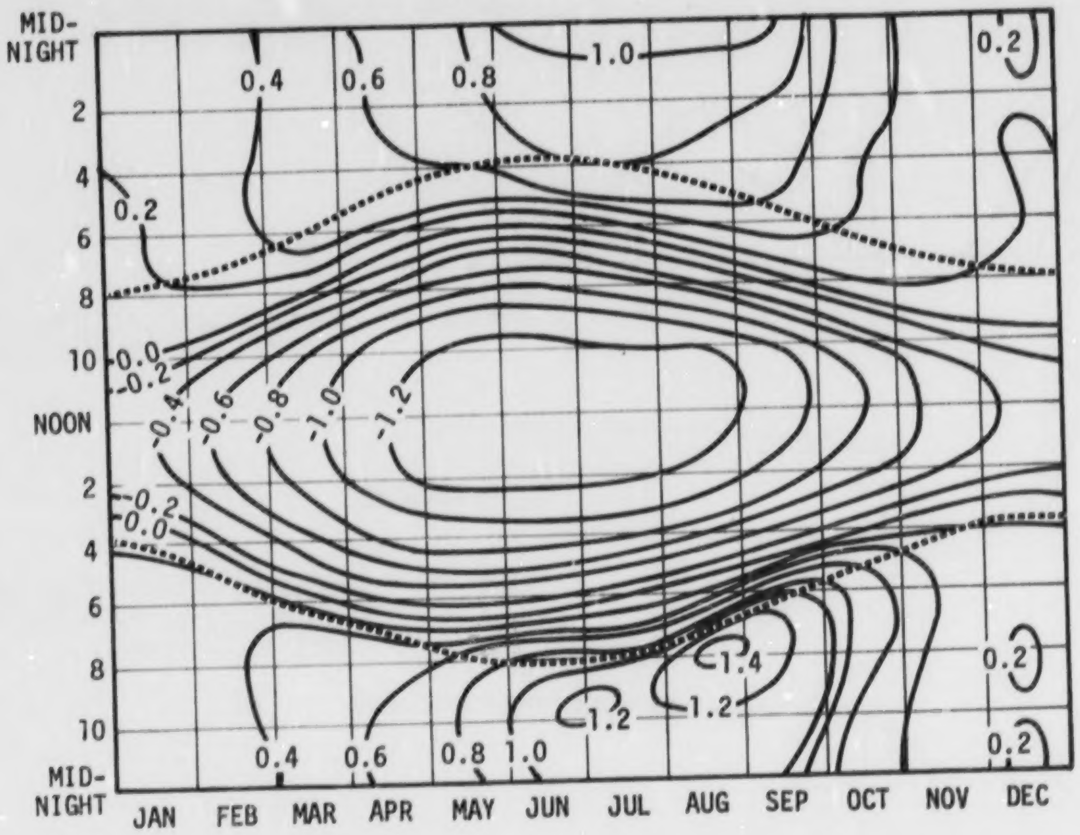


Figure 2-5. Average difference in air temperature (°C) between 2 and 34 meters height measured in Potsdam between 1893 and 1904. The dotted lines show sunrise and sunset times.

Precipitation

Raindrops form on minute particles at elevations well above the levels of primary concern to researchers studying air pollution problems. During the "rain-out" of the condensation nuclei, the raindrop may impact a particle in the lower atmosphere and carry the particle to the ground. This latter "washout" is one, though probably minor, process by which the lower atmosphere is cleaned. Relationships between precipitation amounts and changes in pollution levels are obscured to a large extent by associated larger factors such as stability and wind; precipitation, however, must be considered in an evaluation of any pollution episode.

Steady, light rain or snow is indicative of stable air and limited vertical diffusion, and can, therefore, be accompanied by high air pollution levels. Showery precipitation, on the other hand, indicates rapid vertical diffusion with low air pollution levels. Precipitation has a secondary effect on pollution levels since rain influences industrial and home activities. This effect is not thought to be significant in the Kanawha Valley.

Relative Humidity and Fog

The term "relative humidity" is used to indicate the amount of water vapor actually present in the air in terms of the percent of maximum possible water vapor under existing temperature and pressure conditions. Ideally, if a mass of moist (partially saturated) air is held at constant pressure and cooled, the relative humidity value will increase as the temperature decreases without the addition of new moisture. When 100 percent relative humidity is reached and cooling continues, the moisture condenses as dew, frost, fog, or a cloud, depending on the location and availability of condensation surfaces. Many condensation nuclei are hydrophilic (have a strong affinity for water) and become wetted before the surrounding air is saturated; thus, fog may be present when the air is well below 100 percent relative humidity.

Fog is usually associated with air cooling from below and thus is an indicator of stable conditions and consequent slow diffusion effluents. Limited data indicate an increase in frequency and persistence of fog due to industrialization when a significant increase in hydrophilic condensation nuclei in the air results from industrial activity. Fog also serves to hasten corrosion by depositing dissolved pollutants on exposed surfaces. Reduced visibility at a relative humidity below 70 percent[5] is usually considered to be caused by air pollutants.

Air Pollution Potential

When a relatively large area of the Continental United States is expected to be under conditions conducive to the continuous increase in concentration of pollutants for an extended period of time, an "Air Pollution Potential Forecast" for the area is issued by the Weather Bureau. Local agencies and industries that have arranged with the local Weather Bureau office for the service are then notified and can take appropriate precautions. This forecast of air pollution potential is designed for large-scale considerations extending over several consecutive days at one location. Concentrations of industries and other sources of pollutants as well as geographic considerations such as deep valleys or mountain tops are not treated separately.

Extended periods during which meteorological conditions result in large areas of low wind speed have been termed "stagnation periods," and their occurrence in the eastern United States has been studied by Korshover.[6] This work indicates that the study area averages two stagnation periods of four or more consecutive days a year. During these stagnation periods, the air above, as well as within, the valley can be expected to become progressively more polluted.

Inversions at or near the surface are also conducive to the accumulation of pollutants. This occurrence and persistence of inversions have been analyzed by Hosler[7] who finds low-level inversions exist over the Appalachian Mountain area 30 to 45 percent of the total hours compared to 10 to 35 percent on the Atlantic Coast.

Limited vertical mixing occurs when a neutral or unstable layer is based at the surface and capped by a stable layer. This phenomona is also conducive to the accumulation of pollutants, and has been studied by Holzworth.[8] These factors have been summarized in another paper by Hosler.[9] All of these studies indicate that the Kanawha Valley is an area of frequent poor atmospheric ventilation because of the geographic location. In addition to these relatively large-scale influences, the topography must be considered. Topography is discussed separately, but mention should be made of the fact that valleys are notorious for having inversions and poor diffusion conditions.

DISCUSSION OF DATA

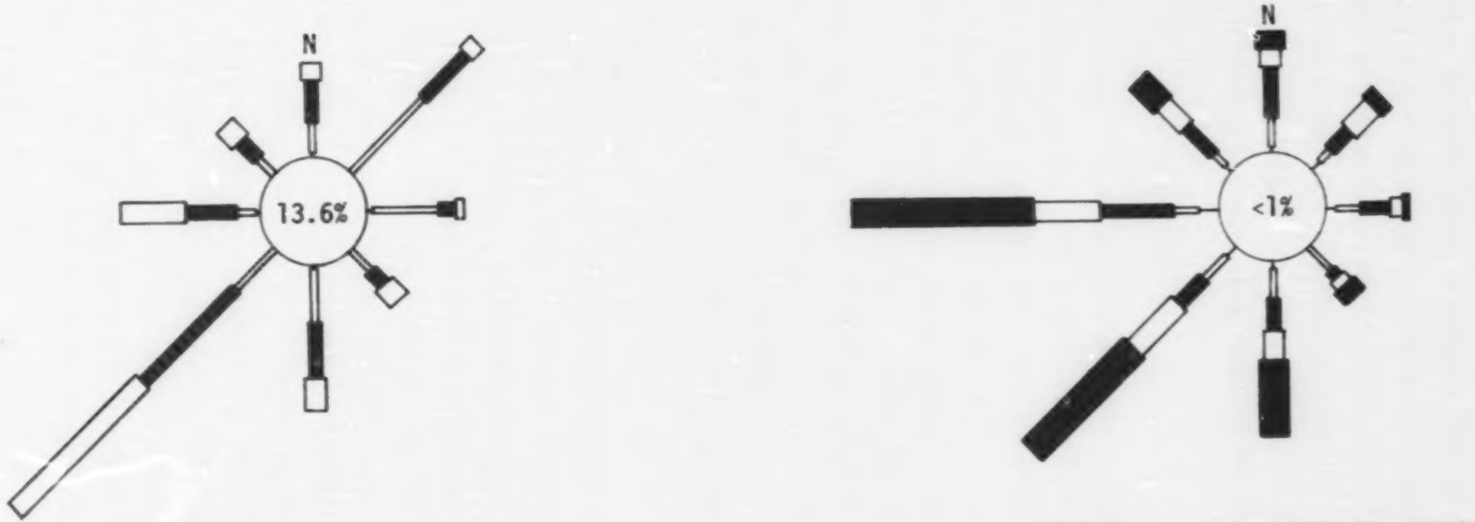
This section shows that the wind data obtained from the Kanawha Airport can be used as a standard for comparison with winds measured within the valley in studying the effects of channeling and valley drainage. A textbook explanation of valley wind flow is followed by a discussion, with data, of the flow found within the Kanawha Valley. In general, a downvalley wind occurs at night while the daytime wind is related to the larger wind pattern of the eastern United States. Pyrheliometer data show a loss of solar radiation on the valley floor as compared to the valley rim in the Charleston area. Sun photometer readings confirm that less radiation reaches the valley floor in the industrial area than in relatively clean areas. An analysis of temperature data, from both hygrothermographs and tethered balloon observations, indicates that inversions with accompanying slow dispersal of pollutants are very frequent in the valley. Tabulated inversion frequency data by season and depth of inversion are presented. Temperature profiles tracing the formation and breakup of a typical inversion are included as well as a short subsection on the relation of cloudiness to inversion persistence. This discussion section closes with the subsection on Climatology and Topography which compares the climatology of the study period to normals and shows that the year 1965 was, in all important respects, a normal year. Thus, the study results can be applied to future years with confidence.

Wind Data

In order to distinguish between the general windflow over the area and the local windflow due to valley effects, the Kanawha Airport winds are used as a reference in this study. The use of the Kanawha Airport data as a standard is justified by comparing this data (measured on a hill outside of the valley at essentially hilltop level) to the Huntington, West Virginia, radiosonde measurement of wind at 2,000 feet above surface. In this comparison, the 50 mile lateral displacement between observation points is insignificant; the 2,000 feet vertical difference, however, should result in a wind shift of nearly 45 degrees due to frictional effects.[10]

Annual wind roses for the year 1965 are presented in Figure 2-6, comparing Kanawha Airport surface wind and Huntington wind 2,000 feet above surface. The Kanawha Airport's predominant southwest wind is 45 degrees counter-clockwise from the predominant west wind at 2,000 feet, as called for by frictional considerations. Wind speeds are also reduced at the airport, as is expected. The 6 percent increase in airport northeast winds over the east winds aloft appears to be nighttime drainage into the Elk Valley. The increase is in the 3- to 4-miles-per-hour group, the speed range of drainage winds rather than in stronger wind classes. Thus, the airport winds can be taken as related to the general flow over the area, and marked deviations from airport winds can be attributed to local effects such as valley drainage and channeling.

General Wind Flow in Valleys - The topography of the Kanawha River region leads one to expect a mountain and valley wind regime. These winds, of considerable importance in hilly country, have been investigated by Defant[11] and others. Mountain-valley wind patterns are characterized by a marked diurnal variation in direction and speed while the wind above is fairly steady. An idealized description of valley winds, given by F. Defant[11] on the basis of earlier work, is as follows: Before sunrise there is a steady movement of air down the valley into the plain, the so-called mountain wind. As the sun rises, the sloping sides of the valley are warmed and buoyant air begins to move up the slopes to descend again in the center of the valley. The upslope wind prevails until about noon, when this wind is joined by a wind blowing up the valley from the plain. In the late afternoon, the valley wind dominates and the upslope wind weakens and disappears. In the evening, the cooling of the air in contact with the upper parts of the sloping sides starts a downslope, or katabatic, wind, which ultimately produces a typical circulation in which air rolls down the slopes and is pushed up in the center of the valley. Later at night the katabatic circulation is replaced by the mountain wind, and a steady



KANAWHA AIRPORT SURFACE WIND ROSE

HUNTINGTON 2,000 FEET WIND ROSE

Figure 2-6. Comparison of 1965 annual wind roses for surface and 2,000 feet above surface.

drift of air from the head of the valley into the plain continues until dawn. In those meteorological situations with a locally strong pressure gradient, the upper wind frequently sweeps to the surface and predominates, even during the nighttime.

Wind Flow in the Kanawha Valley - Winds in the Kanawha Valley are strongly influenced by the meandering character of the valley as well as by local heat sources such as the industry on and near Blaine Island, and by the river itself. Each separate heat source warms the adjacent air, which then rises to a new density level while the lowest layer of air is drawn into the area of warming to replace the rising air. Figure 2-7 is an idealized cross section of such a valley flow, showing the nighttime air flow down the valley's sloping sides and up over the relatively warm water.

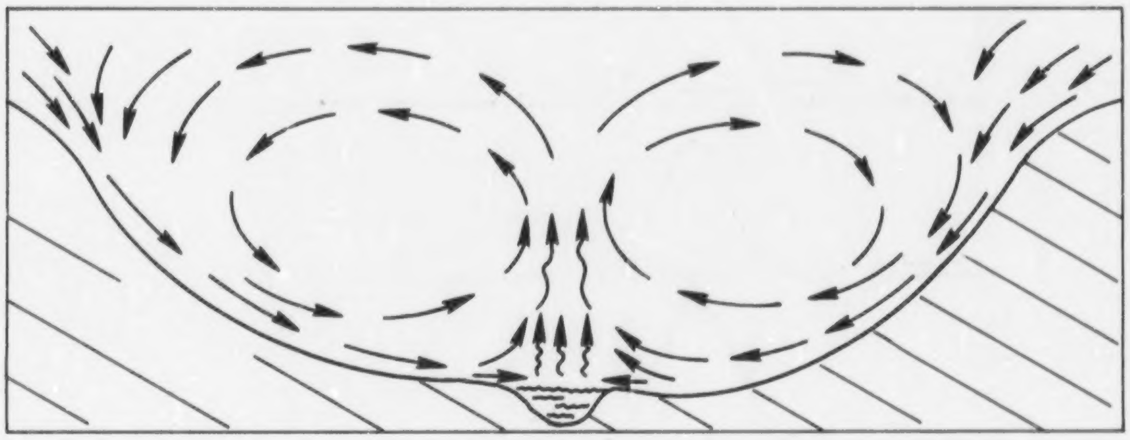


Figure 2-7. Idealized cross-section of a valley and river showing nocturnal air flow.

Wind data from the State Office Building is compared with that from the Kanawha Airport as typical of the contrast between valley locations and the more general wind flow at hilltop level. The State Office Building wind system was exposed at 110 feet above the level of the Kanawha River in the Charleston section of the valley where the downvalley axis is to the northwest (300 degrees) and the valley walls are effectively 300 feet above the river. The airport wind system is exposed 310 feet above the river, being on a flattened hilltop northeast of the valley. Figure 2-8 presents curves of the summertime mean frequency of occurrence of wind directions for even hours at the airport and at the State Office Building. During the daytime, both curves peak on the southwest wind and the hilltop curve's peak remains southwest throughout the night. The valley curve shifts to a maximum in the southeast (down the valley) for the night hours.

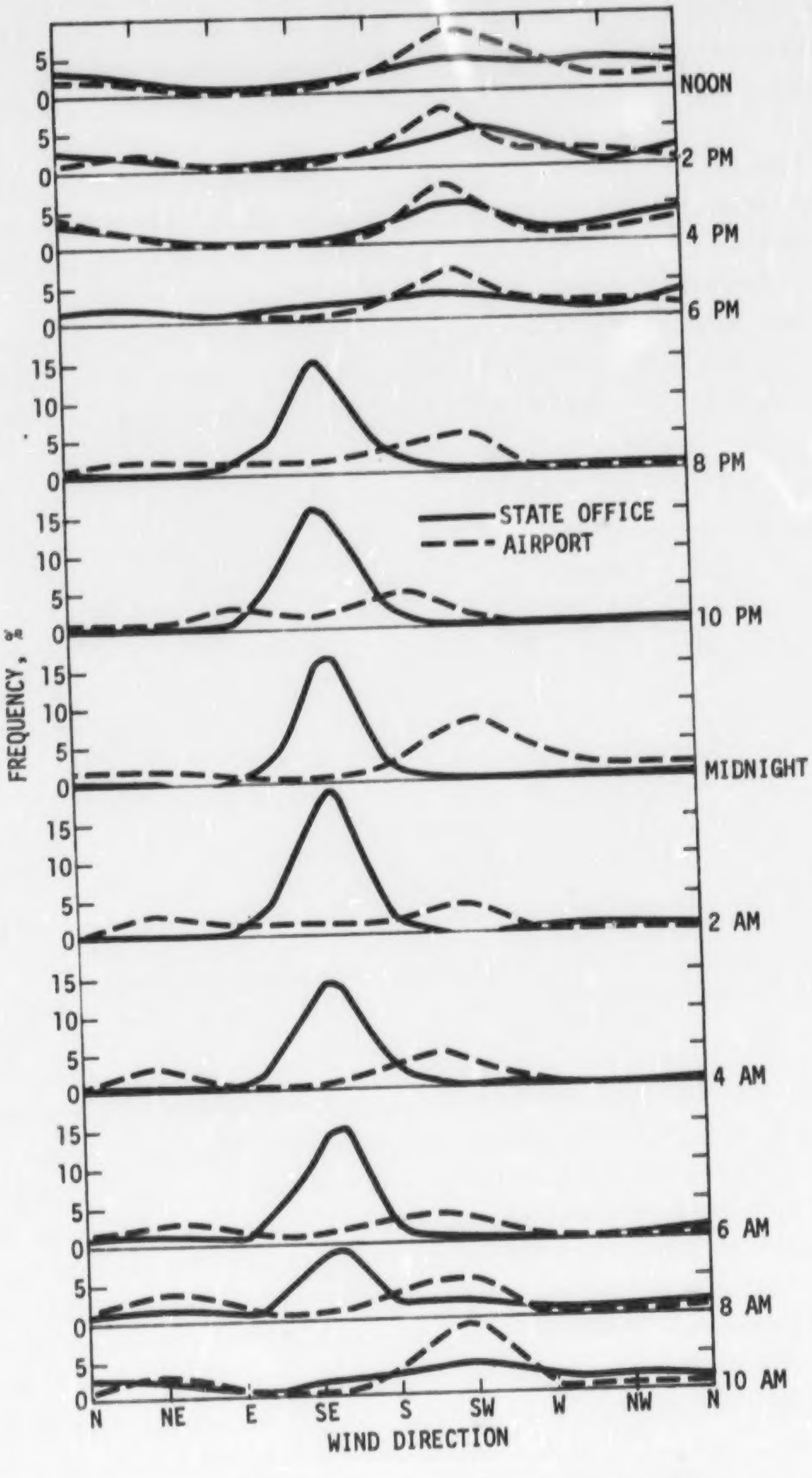


Figure 2-8. Hourly wind directions at State Office Building and at airport for summer season.

Nighttime drainage winds and channeling by the valley are further illustrated by the sets of wind roses presented in Figures 2-9 through 2-12. Figure 2-9 presents the daytime winds for summer and winter. Some reduction of the predominant southwest airport wind is apparent at the valley station where this wind had been channeled into an up-valley wind from the northwest. Valley winds are noticeably lighter and up as well as downvalley winds have increased over those reported at the airport.

Nighttime valley and airport winds (Figure 2-10) show little relation to each other. In summer the 7 percent winds in the downvalley direction at the airport become 63 percent within the valley, reflecting the valley drainage flow. On winter nights the frequent storms with strong, turbulent, unstable winds from the southwest as recorded at the airport are channeled and appear in the valley as winds from the northwest much of the time. Northeast winds are also frequent at the airport in winter and are nearly nonexistent in the valley due to channeling into a downvalley direction where these winds are combined with the lighter drainage winds. Spring and fall seasons show similar channeling and drainage flow patterns.

Most locations show some daytime channeling and a pronounced downvalley nighttime flow. Beginning time of the latter is strongly influenced by early shadows in sections of the valley running in a north-south direction. Eddy currents where secondary valleys or sharp bends disrupt the flow must also be expected, and at times upper winds are parallel to long reaches of the valley and dominate those reaches while valley flow occurs in other sections of the river valley.

Records from ten wind recorders located between London and Nitro were considered and the weighted average seasonal winds presented as Kanawha Valley wind speeds in Table 2-1. Heights above the valley floor varied from 30 to 200 feet, averaging 86 feet. The airport data and that from 400 Mountain View have been averaged to represent hilltop wind speeds while the data from the Kanawha Valley Bank Building is presented alone, as these data represent flow within the valley at 280 feet above the surface. Here the wind is less obstructed by surface friction than at the hilltop stations, which are roughly 30 feet above the land. This table indicates that the ventilation rate within the valley is least in summer and fall. Other data indicate generally lower speeds at night than during the day; thus, nighttime in late summer and early fall is considered to be the time of poorest ventilation. An average speed of 3 miles per hour (mph) is considered representative for this time.

Seasonal wind directions for the above stations have been divided into daytime (2 p.m.) and nighttime (2 a.m.) tabulations, and each station is depicted by a

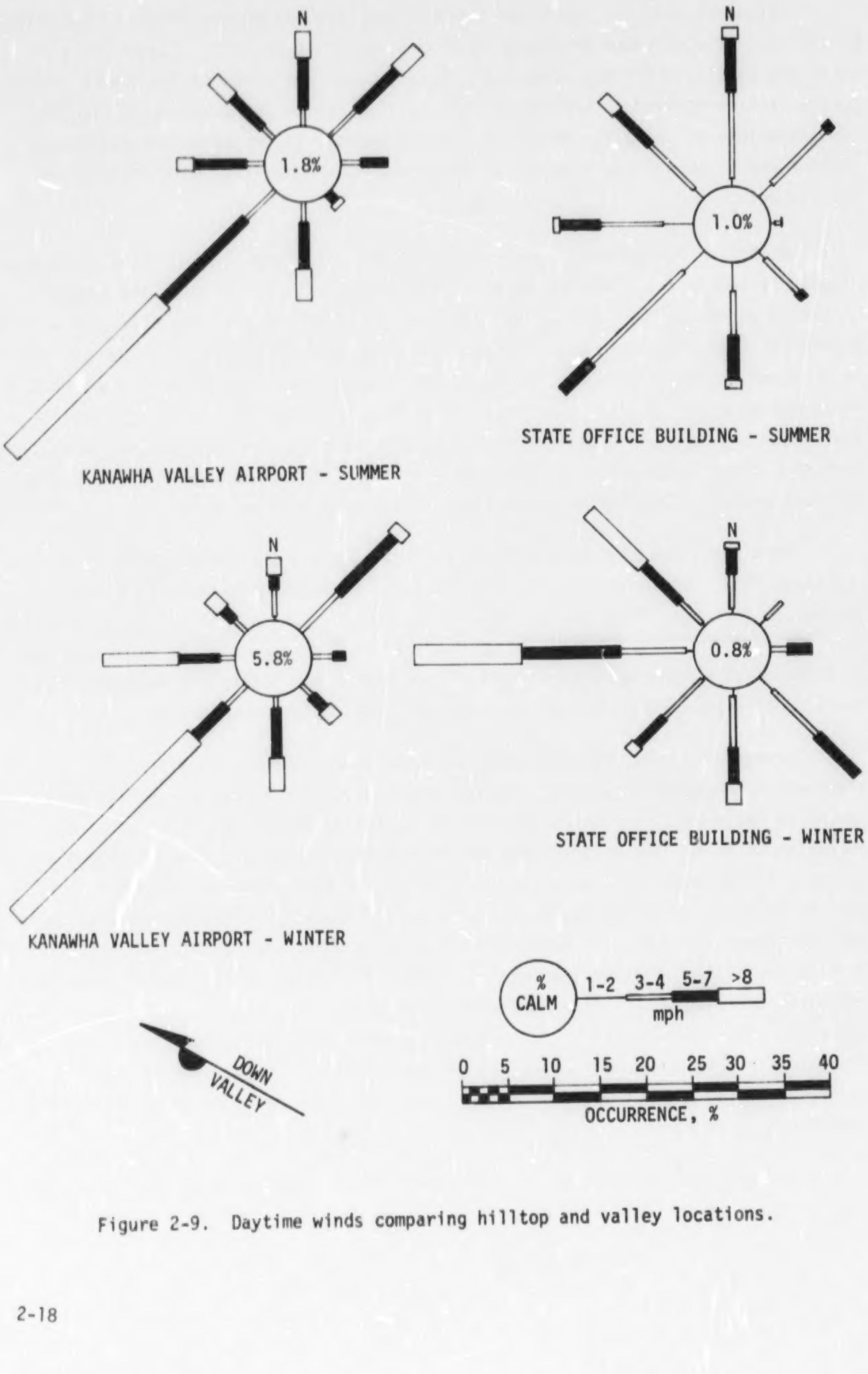


Figure 2-9. Daytime winds comparing hilltop and valley locations.

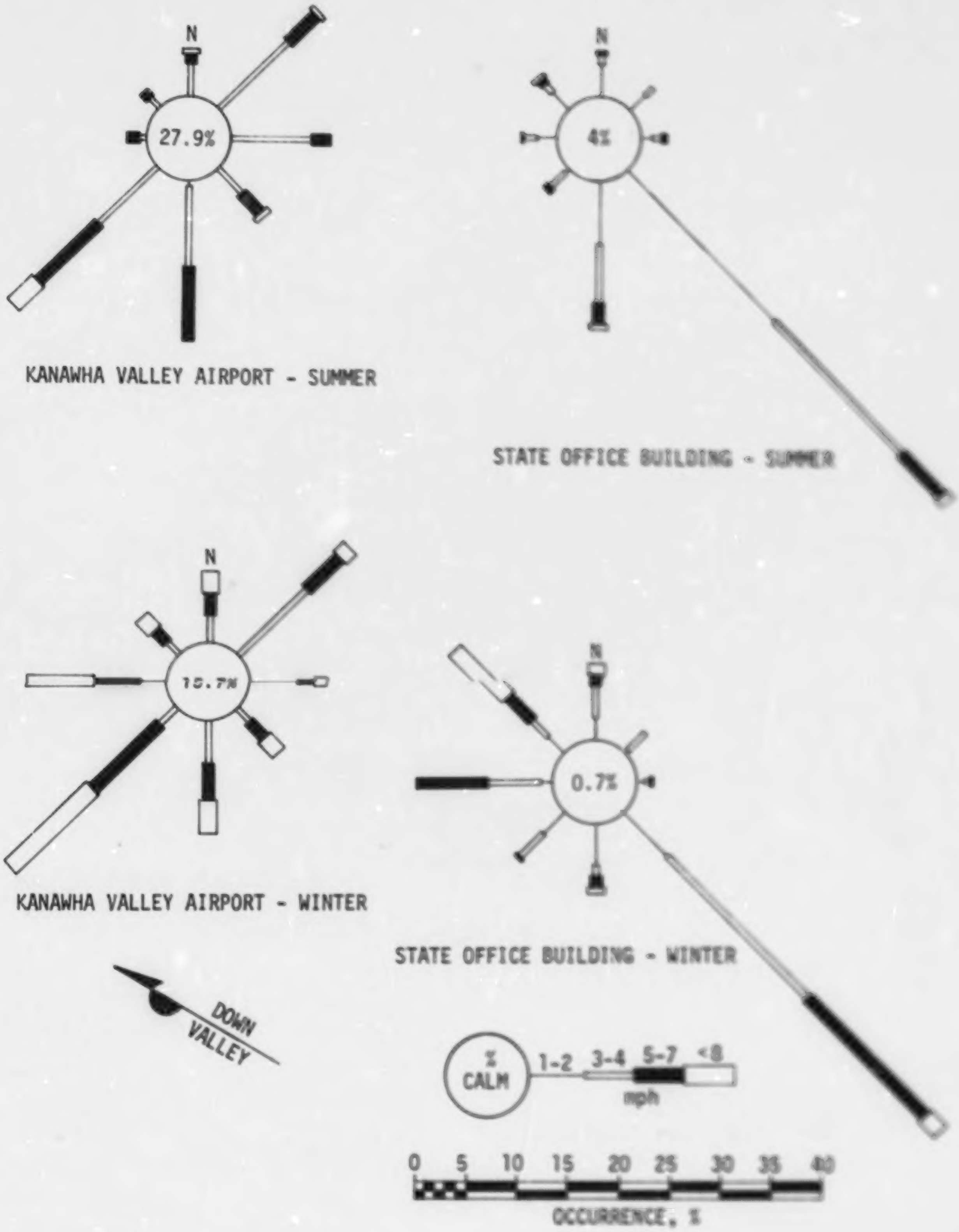


Figure 2-10. Nighttime winds comparing hilltop and valley locations.

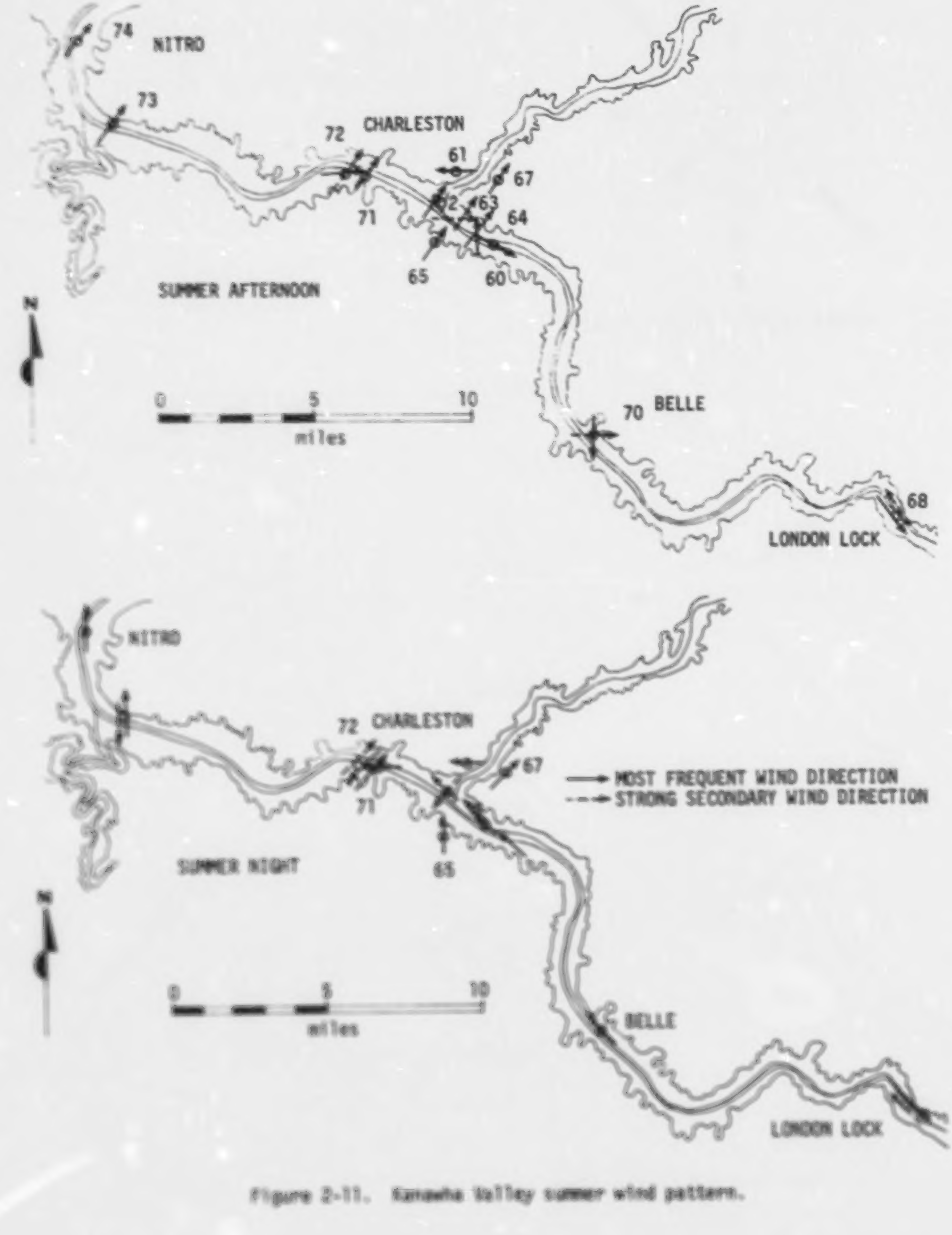

74
NITRO
73
CHARLESTON
72
61
67
62
63
64
71
65
60
SUMMER AFTERNOON
N
0
5
10
miles
70
BELLE
68
LONDON LOCK
NITRO
72
CHARLESTON
67
MOST FREQUENT WIND DIRECTION
STRONG SECONDARY WIND DIRECTION
71
SUMMER NIGHT
65
N
0
5
10
miles
BELLE
LONDON LOCK

Figure 2-11. Kanawha Valley summer wind pattern.

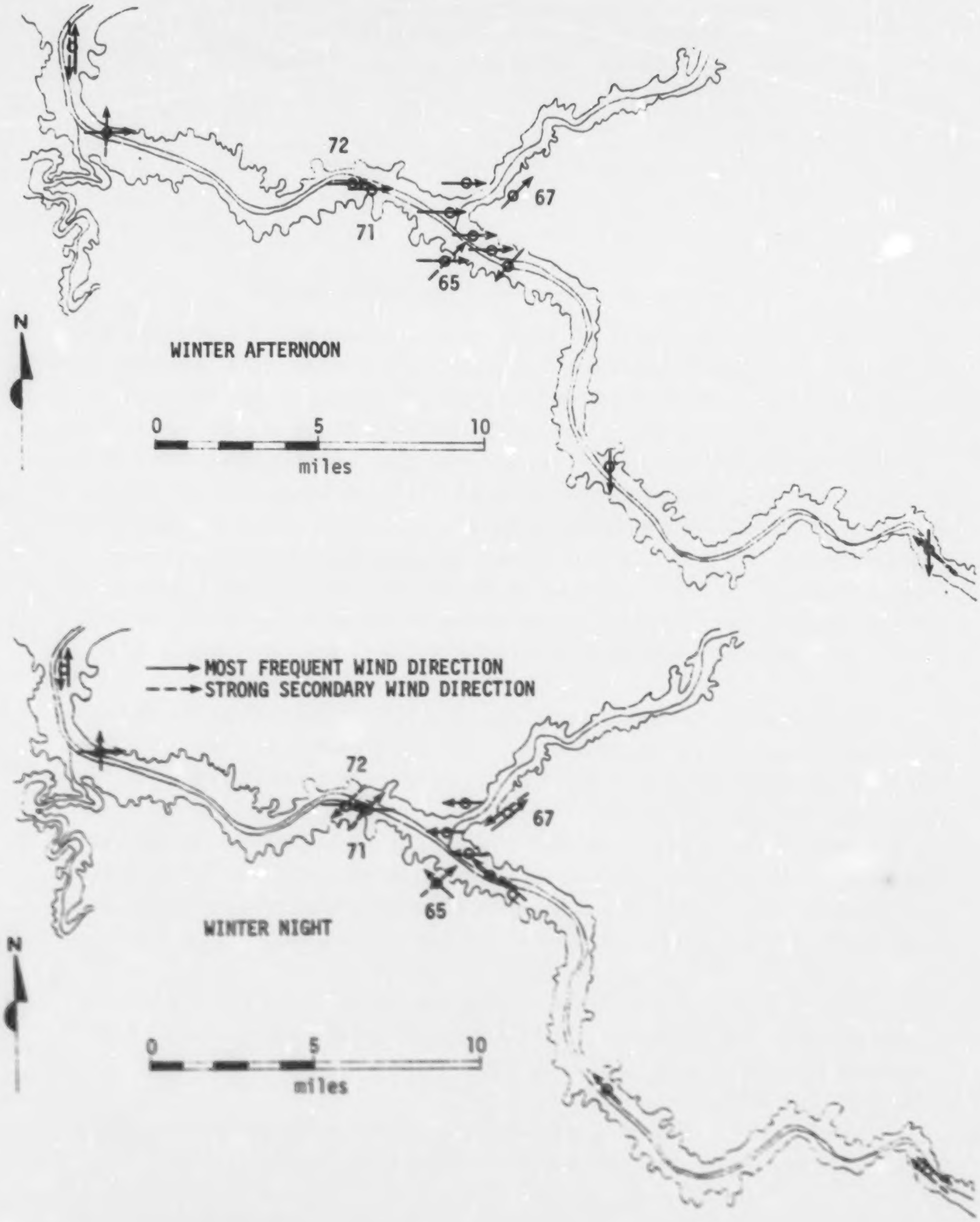

72
67
71
65
N
WINTER AFTERNOON
0
5
10
miles
MOST FREQUENT WIND DIRECTION
STRONG SECONDARY WIND DIRECTION
72
67
71
65
WINTER NIGHT
N
0
5
10
miles

Figure 2-12. Kanawha Valley winter wind pattern.

Table 2.1. AVERAGE WIND SPEEDS BY SEASON IN THE KANAWHA VALLEY AND AT HILLTOP LEVEL (mph)

Effective height above valley floor, feet	Spring	Summer	Fall	Winter
Hilltop 370	7.2	5.3	6.2	7.0
Bank 280	8.3	6.8	6.3	6.4
Valley 86	4.7	3.7	4.2	5.6

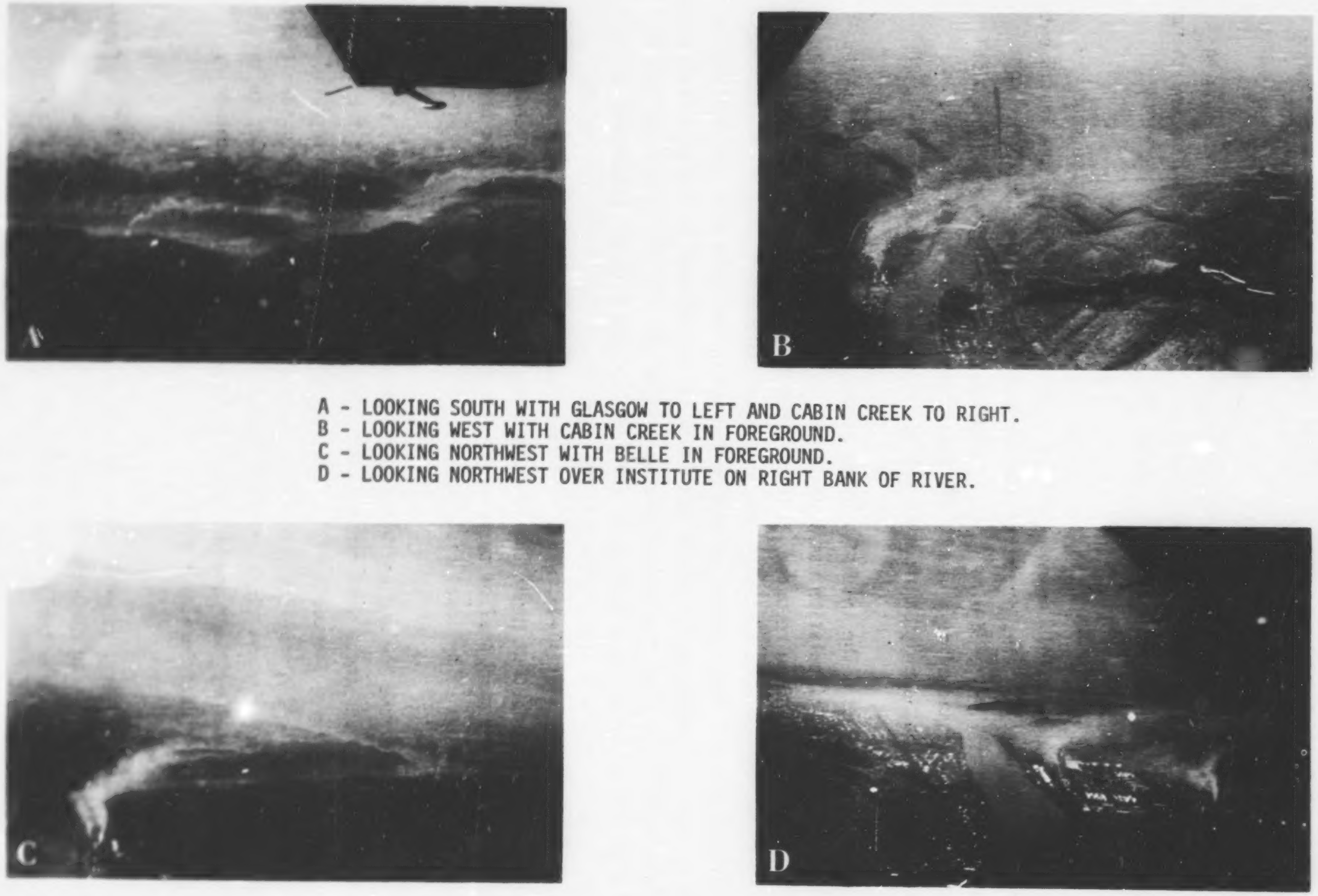
solid arrow pointing downwind at the appropriate point on a sketch map of the Kanawha Valley. Significant secondary directions are indicated by broken arrows. Stations 65 and 67 are outside of the valley and are plotted to show the more general flow at hilltop level. Since spring and fall data are similar, these data have not been included. Figure 2-11 demonstrates that summer daytime winds within the valley generally follow the upper winds except in the deeper sections such as the London station, where channeling is apparent. On summer nights the general flow is downriver while flow at the hilltop stations remains southerly. Winter winds in Figure 2-12 exhibit a similar valley pattern. The secondary winds at stations 71 and 72 are attributed to the heating effect of Blaine Island; in fact, the primary night wind in winter at station 72 is toward this industrial complex.

The four aerial photographs of Figure 2-13 further demonstrate the channeling of pollutants down the valley under stable atmospheric conditions. These pictures were taken at about 6:30 a.m. on April 28, 1966. At that time, station 67 at Kanawha Airport recorded the wind as being from 170 degrees at 7 mph. This appears to be the direction of the upper part of the plume in Figure 2-13 C and D. At the same time, station 70, at Belle, recorded wind from 130 degrees at 7 mph (valley axis direction) and station 72, in South Charleston, recorded wind from 70 degrees at 4 mph (again a flow down the axis of the valley in this region).

Figure 2-13 A is a view to the south across the valley, with the plume from Glasgow following the valley curves to the vicinity of Cabin Creek, where another plume rises and also follows the valley curves.

Figure 2-13 B is a view to the west. The Cabin Creek plume plainly makes the bend along with the valley and merges into the plumes beyond.

Figure 2-13 C was taken to the northwest. Plumes from Belle are prominent in the lower left. The heavy plume is seen to cross the valley and percolate among



A - LOOKING SOUTH WITH GLASGOW TO LEFT AND CABIN CREEK TO RIGHT.
B - LOOKING WEST WITH CABIN CREEK IN FOREGROUND.
C - LOOKING NORTHWEST WITH BELLE IN FOREGROUND.
D - LOOKING NORTHWEST OVER INSTITUTE ON RIGHT BANK OF RIVER.

Figure 2-13. Aerial photographs of Kanawha Valley under stable air condition.

the hills; much additional pollution at a lower level can be seen to be following down the valley.

Figure 2-13 D, an aerial view of Institute, shows two high plumes blowing out of the valley while other lower sources cross the river to St. Albans and thence follow downriver and around the bend toward Nitro.

During each season the winds aloft were measured in an intensive study by the "Pibal" method (visually tracking a free balloon as described in the instruments section of Appendix B). The downriver axis of the valley at Charleston is 300 degrees so that a 120-degree wind (blowing from) is a downvalley wind. The pibal data have been grouped by day, night, and transitional periods and included in Appendix B with the Huntington winds in the two righthand columns.

Intensive Study Winds - The intensive study of July 26 to 31, 1965, was fortunate in that the general circulation was from the north during the entire week. The Huntington Weather Bureau reported winds at 2,000 feet above sea level during this period to be from between northwest and north-northeast and from 4 to 18 mph. Intensive-study pibal measurements at Charleston agree very well with the Huntington data by day; a southeasterly wind in the lower levels, however, persisted each night except on the 29th, when the upper winds were exceptionally strong and the normal nighttime inversion did not form above 150 feet, as shown by the tetersonde data. On the other 4 of the 5 nights studied, the downvalley flow filled the valley as indicated by the 490-foot-level wind. The "surface" (valley floor) wind was easterly, but less well organized at night than the next two levels above. This condition is a reflection of the many shallow currents flowing momentarily across the area from eddy currents generated by local disturbances.

During both the May and the October-November observation periods, strong inversions formed and there were numerous examples of drainage winds at the lower levels of the valley. The depth of the drainage winds seemed to quickly build up to near the height of the valley rim during the May and July series of observations. In the fall, stronger winds aloft affected the air deeper into the valley so that usually only the valley floor and the 260-foot levels showed the full change of direction that indicated drainage winds.

The 710-foot level is well above the rim of the valley, but still is affected by the terrain. The wind direction at the 710-foot level is frequently an intermediate direction between the free air direction and the direction of the river channel.

Since the valley is about 400 feet in depth, the variation in wind speed through this depth was of particular interest. In only one case (7 a.m., in October-November) did the ridge top wind speed average as much as twice the valley floor wind; and during the daytime, the ridge top wind averaged within 25 percent of the valley floor wind speed. The wind speed at 1,000 feet averaged as much as five times the valley floor wind speed at 7 a.m., in May and in October.

During May, pibal observations were also made in Nitro where the valley axis points 028 degrees down valley. The balloons verified a strong downvalley flow, which was both more persistent and extended farther above the valley's floor than that at the North Charleston site. Wind directions are practically identical above 1,000 feet at the two sites. At Nitro the downvalley direction is north-northeast in contrast to the Charleston section of the valley where the axis runs west-northwest. The righthand valley wall is shaded from direct sunlight at Nitro while this wall is not shaded at North Charleston during much of the forenoon and the lefthand wall at Nitro becomes shaded much earlier in the afternoon. This results in less heating of the valley air in the Nitro section and a longer period of stable nighttime drainage wind flow.

During each season tetroon observations were made. Lack of radar tracking equipment and the limited depth of air (400 feet) being studied make these observations difficult.

Afternoon releases were noteworthy for the apparent lack of channeling. Even though in some cases the tetroon touched trees when going over ridges and sank below ridge tops in crossing valleys, there was no directional effect that could be attributed to the terrain. (See May 7 track in Appendix B.)

All morning releases were tracked from the ground by means of two radio-equipped vehicles. In no case did weather conditions (usually very low visibility in the valley) permit aerial tracking for morning runs. With the tetroon's apparent lack of regard for terrain features and the lack of roads running perpendicular to the valley axis, afternoon automobile tracking was not attempted. The afternoon runs indicate that there is little daytime channeling of the wind direction 200 feet above the valley floor, and that when the upper winds are cross-valley, the air within the valley is constantly being replaced. Early morning runs pointed to a complex flow within the valley after sunrise, with vertical currents reaching up into the inversion.

Sunshine

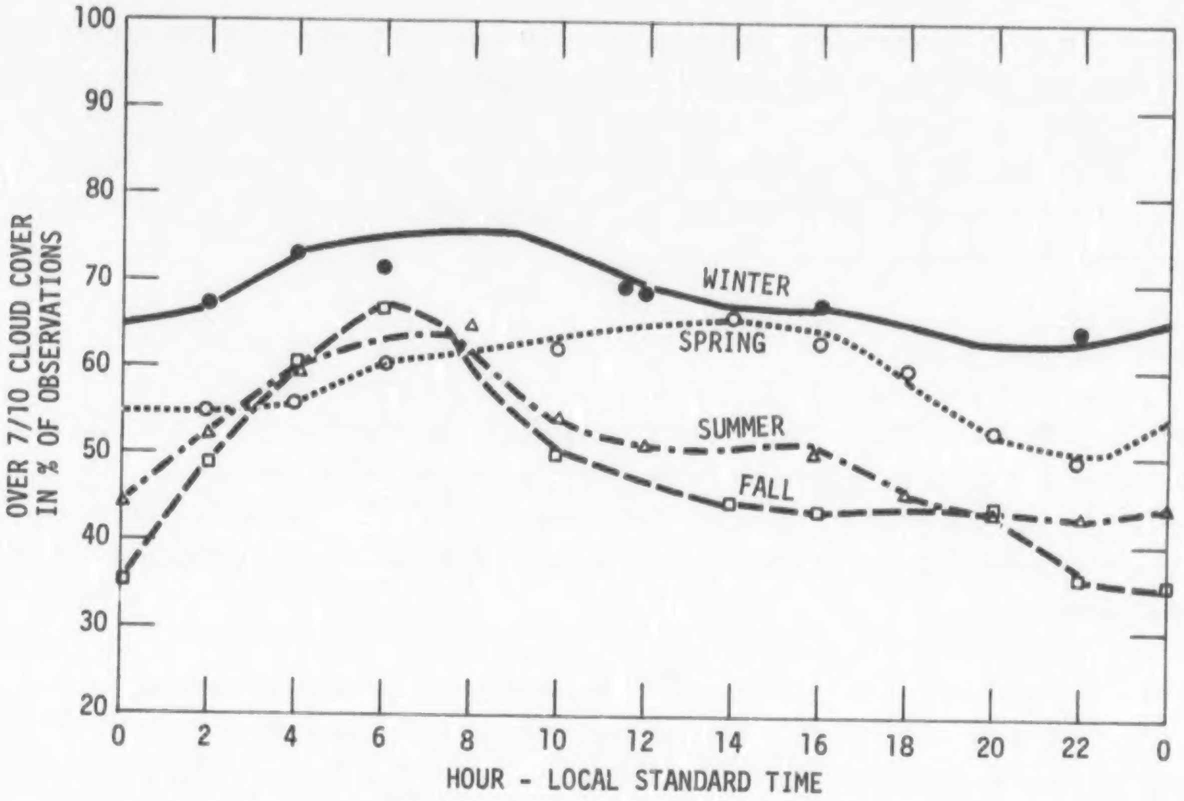
Seasonal cloud cover data from the Airport Weather Station are presented by hour of the day and are discussed as these data relate to solar radiation and air quality. Solar radiation was measured and used to compare pollutant levels outside the valley with those on the valley floor by means of a pair of pyrheliometers. Pollutant levels at various locations along the valley floor were also compared by use of sun photometers.

Cloud Cover - Frequency, by hour, of over 7/10 cloud cover for each season is plotted in Figure 2-14. During winter, and to a lesser extent in the spring, most clouds are associated with large-scale storm systems which are little influenced by diurnal patterns. Summer and fall cloudiness exhibits a strong diurnal nature with the maximum cloudiness of near 65 percent in both seasons being reached soon after sunrise and the minimum of near 40 percent occuring at midnight. These summer clouds are primarily the result of moist layers of air cooling during the night to below the condensation temperature of the moisture present. Relatively thin layers of clouds result. As the saturated layer is warmed by the rising sun, the cloudiness rapidly decreases until cloudy sky is recorded on only 51 percent of the noon observations.

In winter and spring the high frequency of over 7/10 cloudiness during daylight hours tends to prolong the period during which pollutants are retained within the valley by the inversion lid. During summer and fall, cloudiness is much less and local inversions formed during the night within the valley tend to dissipate rapidly after sunlight reaches the valley floor; thereafter, pollutants are carried up and out of the valley by the wind. Late summer and fall are also the seasons when stagnation periods with accompanying large areas of high pollution are experienced.

Pyrheliometer - Periods during each season of the year were chosen for comparison of solar radiation as recorded by pyrheliometers at the Kanawha Airport, which is beyond the north rim of the valley, to radiation received in North Charleston, which is taken as representative of the valley floor. Where records were available, the period chosen was the week of intensive observation. Data in the form of ratios for each season are presented in Table 2-2.

The greatest difference indicated in Table 2-2 was in the winter season; the least, in the spring and fall seasons. During the winter season the stable air in the valley remains for a greater percent of the daytime hours so that the



SEASON	SUNRISE	DATE	SUNSET
SPRING	6:29 AM	21 MARCH	6:39 PM
SUMMER	5:03 AM	21 JUNE	7:53 PM
FALL	6:13 AM	21 SEPTEMBER	6:26 PM
WINTER	7:40 AM	21 DECEMBER	5:09 PM

Figure 2-14. Percent of each hour's observations at Kanawha Airport with over 7/10 cloud cover and related almanac data.

Table 2-2. COMPARISON OF SOLAR RADIATION AT NORTH CHARLESTON AND KANAWHA VALLEY AIRPORT[a]

Season	Period	North Charleston	Kanawha Airport
Spring	April 21-28	100	116
Summer	July 26-31	100	121
Fall	Oct. 25-Nov. 5	100	114
Winter	Dec. 28, '65- Jan. 10, '66	100	129

*Tabulated values are dimensionless ratios based on North Charleston brought to 100 for each season. See Appendix B for further details.

large winter difference is understandable. The small difference in the spring and fall may be due to more changeable weather in those seasons and, therefore, proportionately fewer hours of heavy pollution in the daytime hours. Over the year air pollutants and the greater depth of atmosphere cause North Charleston to receive about 17 percent less radiation than points above the concentrated polluted layer as exemplified by the Kanawha Airport.

Sun Photometer - Sun photometer readings were taken in a study of the variability of suspended particulate matter in the area. The instrument responds to high particulate concentrations with a reduced reading due to the absorption and scattering of solar radiation as described in the instrument section of Appendix B. These readings are converted to turbidity measurements which are inversely proportional to the measured solar radiation. In this work readings through plumes and clouds are avoided.

On March 9, 1966, two observers departed from the Federal Building in opposite directions at 11:07 EST, and took a series of readings ending at 12:12 EST. The upriver observations showed 0.300 or higher turbidity coefficients across the business section of Charleston. Turbidity decreased fairly regularly to the east to below 0.200 at the east end of Kanawha City in the vicinity of Libby-Owens-Ford glass plant. A side trip into the mouth of the Elk River near the airport gave a low reading of 0.110. Meanwhile, the downriver observations had at first decreased from over 0.300 in the business district to 0.230 and then increased between the railroad bridge and the Patrick Street Bridge. The reading reached 0.430 on MacCorkle Avenue at a point opposite the midpoint of Blaine Island and 0.355 opposite the Indian Mound in South Charleston. The value dropped to below 0.200 before the observers reached the Dunbar Bridge.

Another traverse made in the afternoon again revealed high turbidity in the vicinity of the Federal Building. Going northeastward up the Elk River, the observer found that the turbidity dropped to below 0.200 in the vicinity of Magazine Branch. The observer who went in the opposite direction found the turbidity also decreasing with no real increase even in the route through South Charleston. The surface winds and the winds aloft were both such as to carry polluted air away from the route, which was along the Kanawha River and thence up Davis Creek.

A dual traverse made on July 8, 1966, from the Kanawha City Bridge to North Charleston covered the northeast side of the valley. One observer followed the bank of the Kanawha River as closely as roads permitted, and the other followed a course as close to the valley wall as possible. The observer following the valley wall found much higher turbidity readings, probably because, as other evidence has indicated, on sunny days the air along the sides of the valley rises, and air in the center of the valley sinks and decreases the thickness of the polluted layer in the center of the valley.

This set of observations was made in an hour when relative humidity was less than 40 percent. Reductions in turbidity due to increased ventilation probably were occurring, but not by enough to be readily noticeable.

In all cases turbidity increased in the vicinity of downtown Charleston, and usually remained high or increased downstream to a point beyond the South Charleston industrial area.

Temperature and Stability

In the following sub-paragraphs the hygrothermograph data are discussed and related to stability by season and by time of day. The section of tethersonde data presents specific temperature profiles measured in the free air during periods of intensive study and relates the free air measurements to the hygrothermograph data.

Hygrothermograph - Hygrothermograph data were used in determining the depth and frequency as well as the persistence of inversion within the valley. In order to obtain more representative values, valley stations 17 and 53 were averaged, as were hill stations 65 and 67. Corresponding temperatures within these pairs were usually within 2 degrees of each other, both plus and minus differences being present in a random manner. Recorded differences within the pairs are regarded as lateral temperature fluctuations rather than instrument exposure differences, and the average is considered more representative of the whole area than either taken alone. Temperatures measured on a hilltop as a substitute for free air temperatures must be qualified, since the daytime free air some distance laterally from a hilltop may be 5 degrees or more cooler than that immediately over the hill as was shown by Humphrey's comparative readings made at the National Reactor Testing Station.[12] This lateral temperature difference normally reverses at night. Duration and frequency of inversions estimated here are thought to be correct; intensities are open to some interpretation. Figure 2-15 presents this hygrothermograph data for December 1964 to March 1966 by season so that two winters are averaged with seasons running from the first of the month. For brevity, spring and fall are averaged as one season.

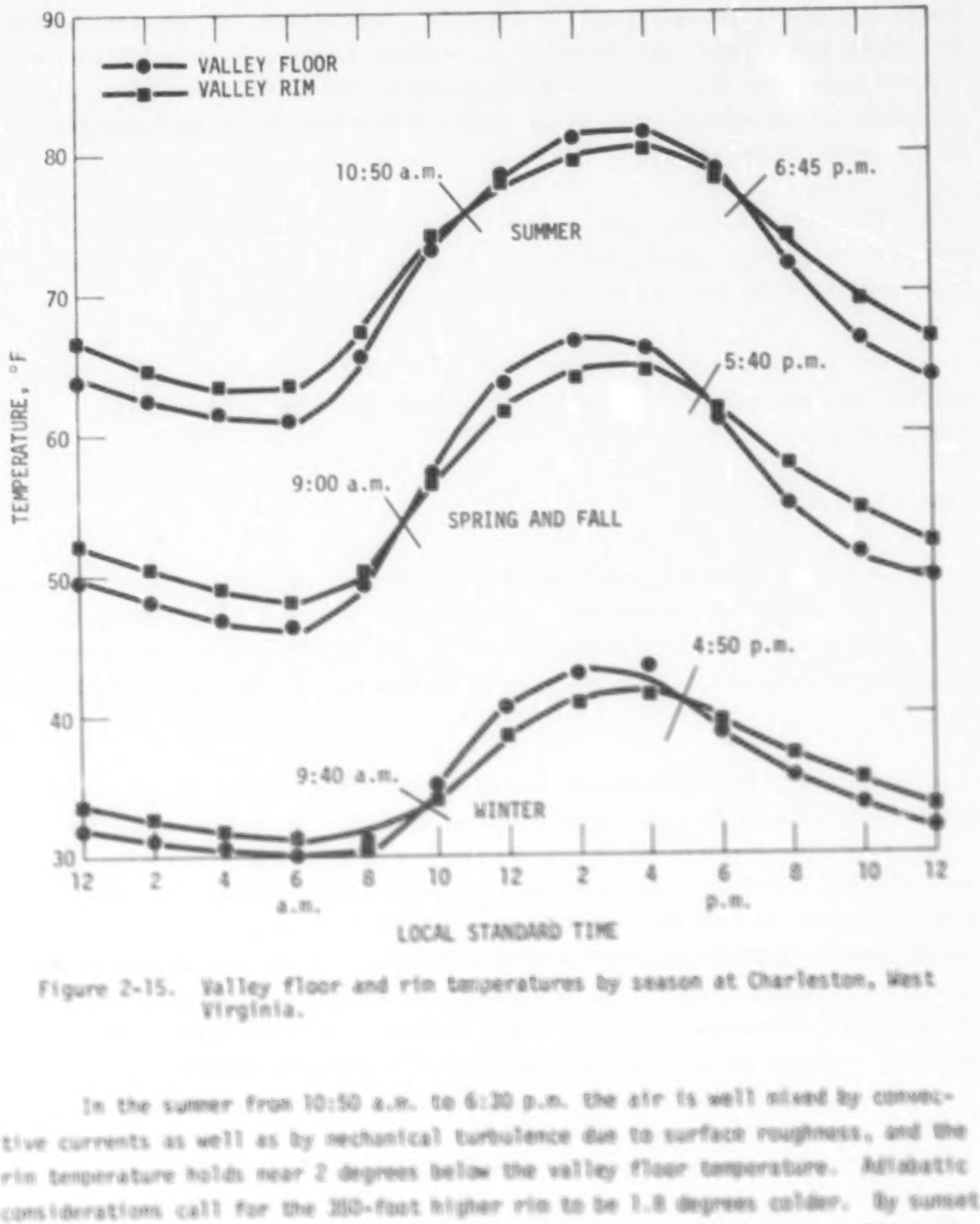


Figure 2-15. Valley floor and rim temperatures by season at Charleston, West Virginia.

In the summer from 10:50 a.m. to 6:30 p.m. the air is well mixed by convective currents as well as by mechanical turbulence due to surface roughness, and the rim temperature holds near 2 degrees below the valley floor temperature. Adiabatic considerations call for the 350-foot higher rim to be 1.8 degrees colder. By sunset the afternoon shadows in the valley have resulted in more rapid valley cooling and the temperature becomes 2 degrees less than that on the hilltop. This condition remains so until sunrise as the cooler air drains into the valley. During the winter the valley becomes warmer than the hill soon after sunrise whereas the summer hill and valley temperatures do not become equal until the late forenoon. The fact should be noted that the winter temperature change from day to night is about half of that in the summer. These differences are due to the shorter daylight hours of winter as well as to the stronger cold winds and more presistent cloudiness of winter. The valley inversion is present 66 percent of the year, being most frequent in winter at 70 percent and falling to 64 percent in the spring and fall combined season.

Valley station 02 is 60 feet and station 63 is 210 feet above the valley floor. Both are in downtown Charleston on rooftops. These, in conjunction with the valley floor and hilltop stations already described, are used to further define the valley inversion. The 60-foot layer exhibited an inversion at sunrise on over 92 percent of the mornings during the year. The exceptions are associated with strong cold winds above the hills blowing nearly along the valley axis and sweeping to the valley floor.

Inversion frequency at sunrise to at least the level indicated is tabulated in Table 2-3 by season. The 210 and 300-foot levels are from the above hygrothermograph data, and the 500-foot data are from Hosler.[7]

Table 2-3. INVERSION FREQUENCY AT SUNRISE AT VARIOUS ELEVATIONS IN KANAWHA VALLEY

	Percent of sunrises with an inversion	
	Through	
Season	210 feet	300 feet
Spring	92	68
Summer	78	66
Fall	92	64
Winter	76	74

Shallow inversions are to be expected at night during all seasons, but most frequently in spring and fall. Hosler[8] has found that an inversion below 500 feet exists 28 percent of the year over the airport at Pittsburgh, Pennsylvania. A reasonable inference is that about 30 percent of Charleston's inversions extend several hundred feet above the valley rim because of a more general inversion in the area.

Intensive Study Temperature Aloft - From air temperature data gathered [illegible] each intensive study period indicate a temperature regime in the valley in [illegible] the temperature - height profile is essentially adiabatic during the afternoon a develops a strong inversion after sunset, followed by a change to nearly isothermal in the early morning hours. The change from inversion to isothermal accompanies the onset of downvalley flow with the attendant mechanical mixing due to surface roughness. This same temperature regime was indicated in the hygrothermograph data already discussed. The tethersonde data indicate that the nighttime cooling extends well above the valley rim and that the diurnal change in temperature becomes progressively smaller at higher levels in the free air.

The July 29-30 series of temperature profiles is typical of summertime under a cold northerly flow aloft. At the right side of Figure 2-16, comparing the 4 p.m. profiles of the 29th and the 30th, approximately 2 degrees warming throughout the 700-foot layer during the 24-hour period is shown. The layer was essentially adiabatic both days at this time. Sunset was at 7:40, and the 8 p.m. curve of the 29th shows overall cooling of nearly 4 degrees and additional cooling at the 50-foot level of another 7 degrees. The inversion was pronounced from 150 feet down and weak below 400 feet. At this time smoke from surface fires appeared layered as it drifted across the valley, while plumes above the valley rim continued to spread vertically (the "lofting" of Figure 2-4). The 10 p.m. ascent shows a sharp inversion to have existed from 300 feet down and an isothermal layer from 300 to 700 feet. Diffusion at this time was poor at all levels below 700 feet, and layers of thick smoke were likely at many levels. The 4 a.m. run of the 30th indicated near isothermal air at all levels. The downvalley flow was probably well developed, and the air had become isothermal through mechanical mixing in the valley. The State Office Building wind system (at 110 feet) registered northerly wind of about 6 mph at 4 p.m. on the 29th. From 8 to 10 p.m. it was calm to light and variable. By midnight the wind was at 3 mph and out of the southeast and remained so until 10 a.m., on the 30th, when it returned to the daytime light northerly flow. The wind shifted again from north to southeast after 8 p.m.

The 6 a.m. run was almost identical to the one at 4:10 a.m., July 30, but additional cooling was evident above 300 feet. Sunrise was at 5:26; direct sunshine into the valley floor had not yet changed the nighttime regime, however. By 8 a.m. pronounced warming was apparent and a super-adiabatic layer existed below 200 feet. ("Fumigation" as shown in Figure 2-4 would be expected.) At the valley rim and above, smoke drifted in layers. Rapid heating of the lower 700 feet was apparent in the following runs, and the whole layer mixed into the upper flow.

The warm airflow of January 25-26 is shown in Figure 2-17 as measured by tethersonde. During the period Charleston was in the warm sector of an approaching storm system that produced a prolonged strong inversion condition. The January 25,

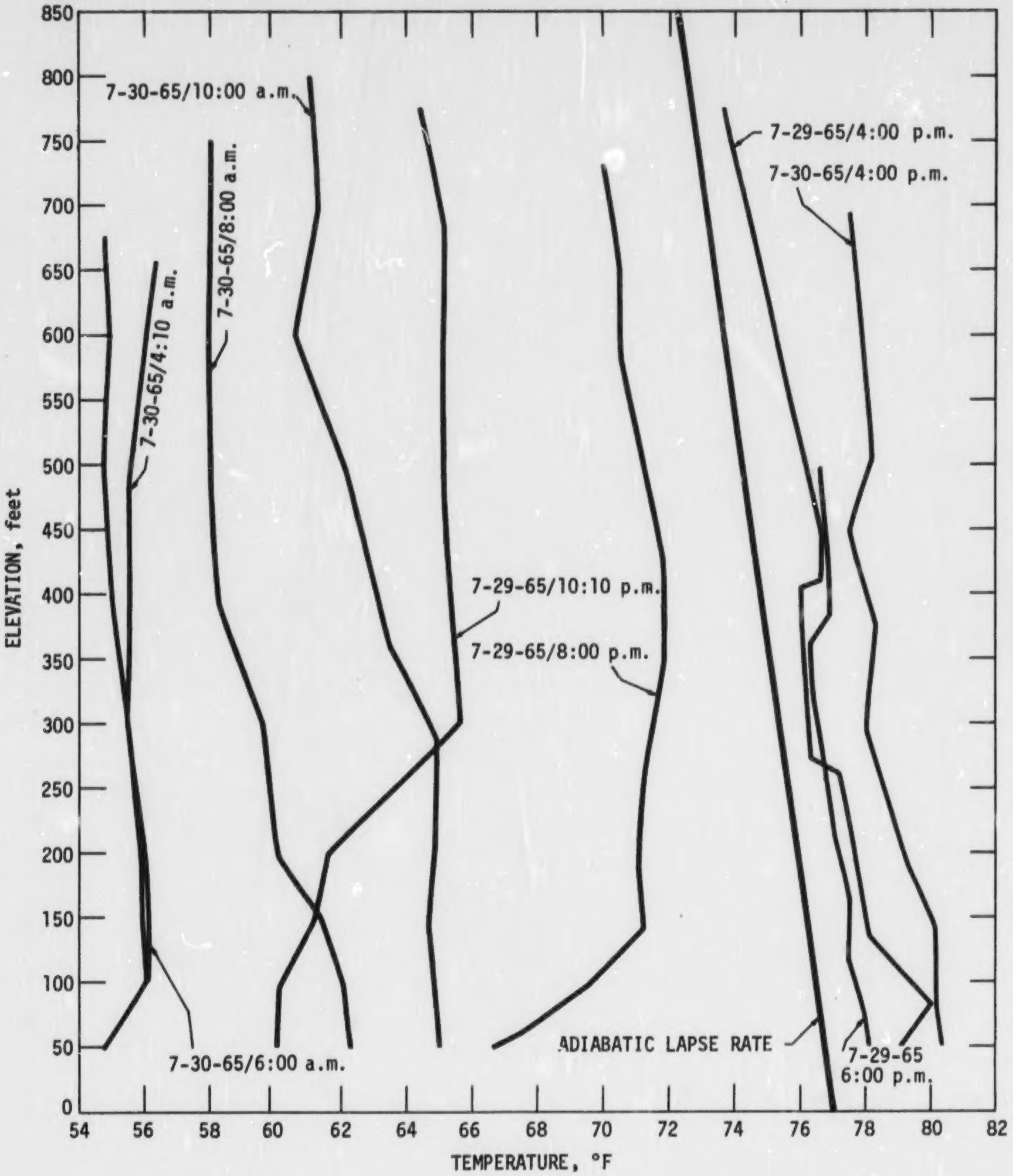


Figure 2-16. Temperature profile from tethersonde in North Charleston, Tru-Temper Kelly Works observing site. Weather was clear with ground-fog forming near sunrise and increasing cirrus clouds on July 30, 1965. Sunset 7/29 - 7:40 PM Sunrise 7/30 - 5:26 AM EST

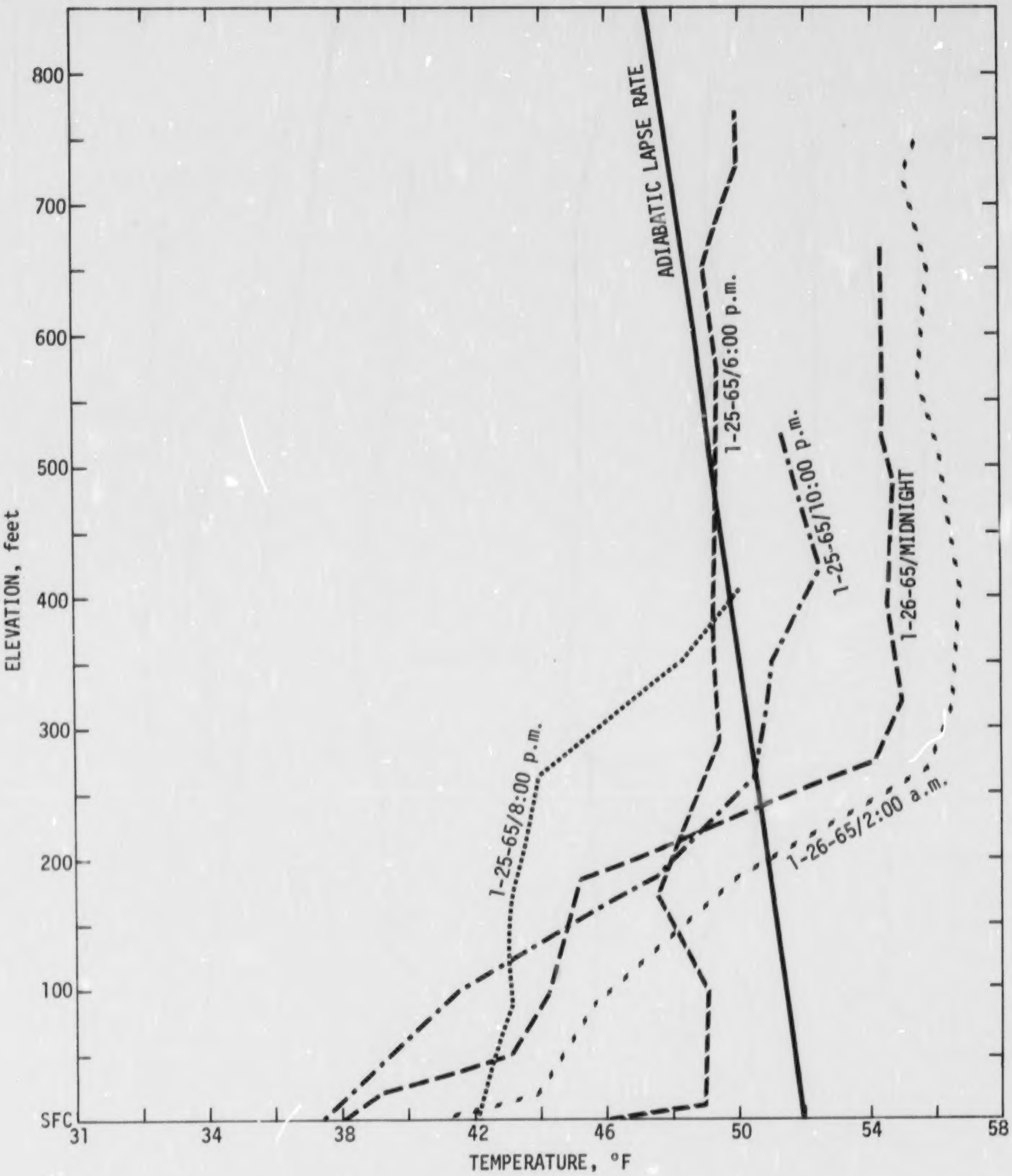


Figure 2-17. Temperature profile from tethersonde observations taken in Charleston just east of City Hall on January 25 - 26, 1965.
Sunset 1/25 5:41 PM Sunrise 1/26 7:37 AM

6 p.m. ascent showed an essentially isothermal condition, and the 8 p.m. ascent indicates surface cooling of 6 degrees with the 400-foot layer remaining unchanged. At 10 p.m., the temperature inversion had intensified both from surface cooling and from arrival of much warmer air at levels above 200 feet. By midnight, mechanical mixing had taken place and thereafter warming continued at all levels until the front passed later in the morning. A 16 degree temperature difference was maintained between the surface and the 350 foot levels, as recorded on the midnight and 2 a.m. ascents. This agrees well with the 15 degree to 20 degree difference recorded between the hygrothermographs at Charleston water treatment plant and at Mountain View 350 feet above. Spring and fall observations further substantiate the diurnal pattern of unstable lapse rate condition by day becoming an inversion at night except when strong winds hold the whole layer near adiabatic.

River Temperatures - An examination of river water temperatures revealed the water to be warmer than the minimum air temperature during the night at all seasons and warmer than the 24-hour mean air temperature except during March and April. Heat stored in the river water serves to cause nighttime warming of the air resulting in upward air currents over the river as illustrated in Figure 2-7. These upward air currents reinforce the upward thrust of air due to the inflow of cool air from the valley walls toward the valley center.

Climatology

A comparison of the Kanawha Airport climatic averages with the airport data for the period of the study shows that the weather was normal during the study period. Meteorological conclusions can therefore be applied to future normal years. The data on which this statement is based are presented below.

Figure 2-18 indicates that winds for 1965 were near normal in both speed and direction. Since the available climatic data for the present exposure are only for 5 years, the wind speed data from this and the former location have been averaged by months for 17 years and are presented in Figure 2-19. During each month of the study period, except October 1965, the speed was within 1 mph of the long-term average; thus, the wind speed during this study was remarkably "average."

The bar-graph of degree-days presented as Figure 2-20 indicates the study was conducted during an average period, although January 1965 was somewhat colder than normal, and January 1966 was exceptionally cold. The graph of average maximum and minimum temperatures (Figure 2-21) follows the same pattern with the exceptionally cold January of 1966 being again apparent.

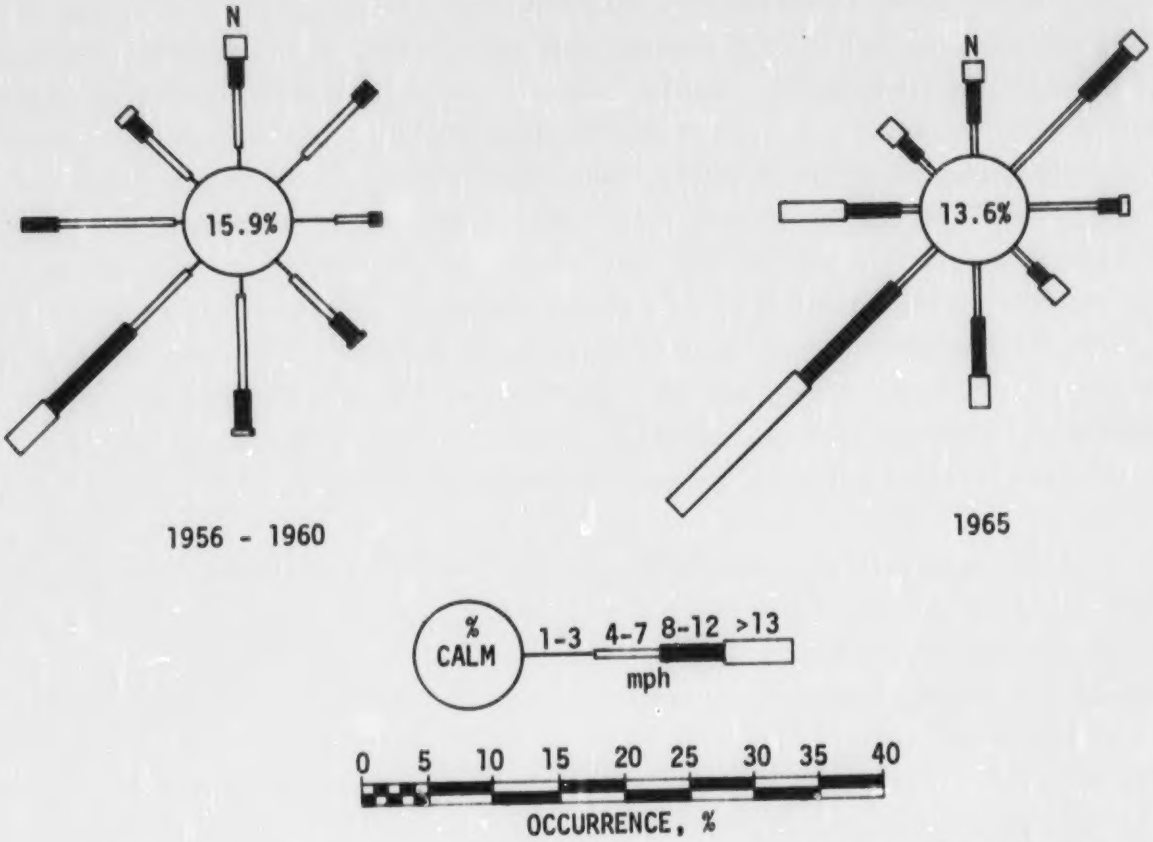


Figure 2-18. Wind roses for Kanawha Airport, Charleston, West Virginia, comparing the year 1965 to the average year.

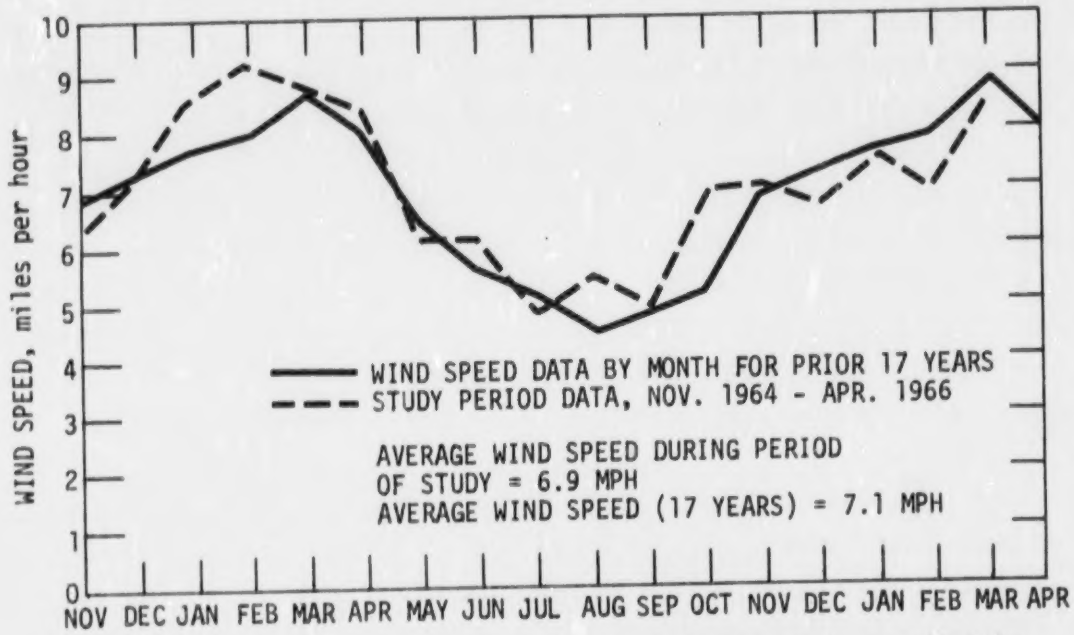


Figure 2-19. Kanawha Airport wind speed during study averaged by months compared to prior 17 years averaged by months.

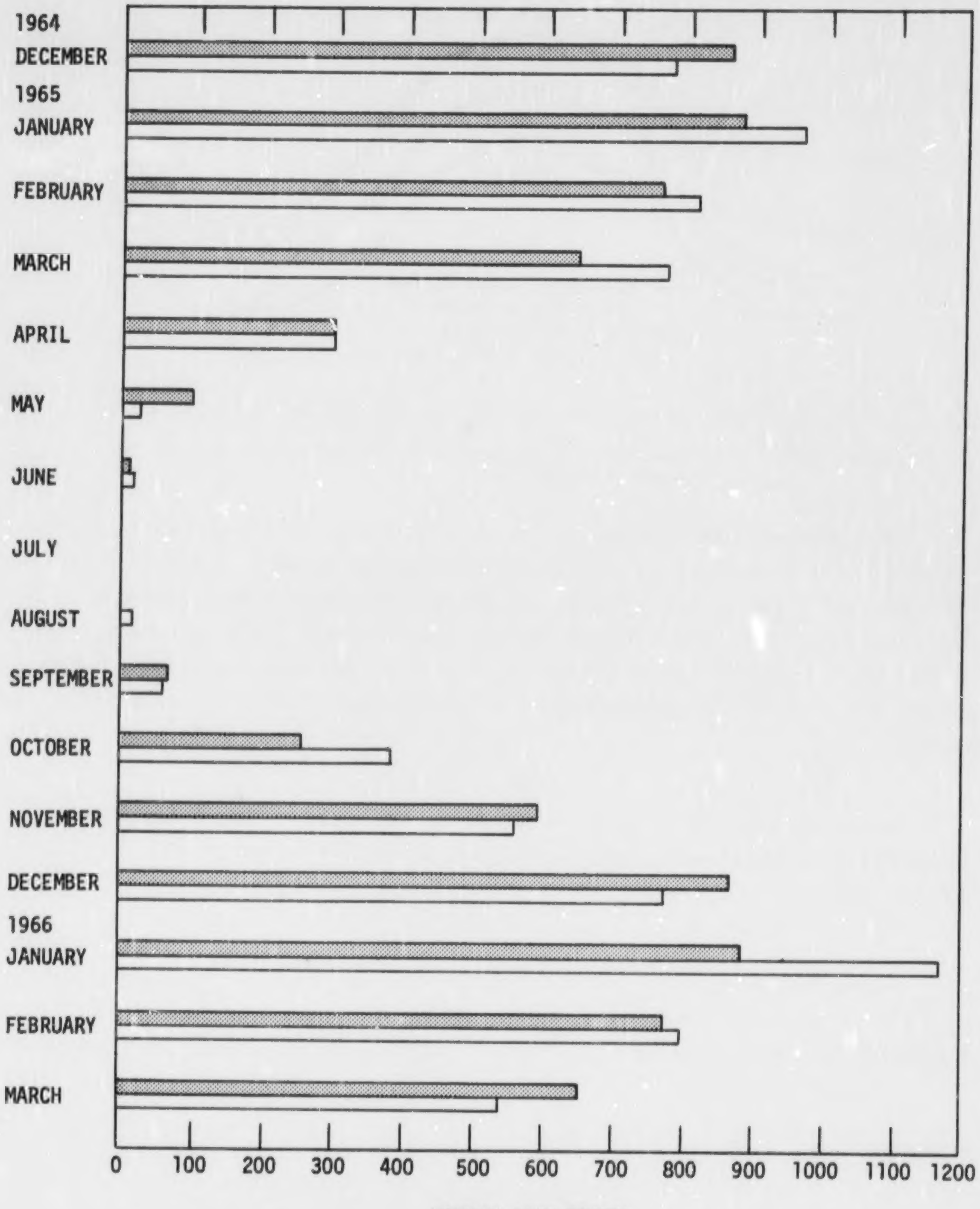


Figure 2-20. Comparison of study period degree days (open bars) to normal degree days (solid bars) for Kanawha Airport, Charleston, West Virginia.

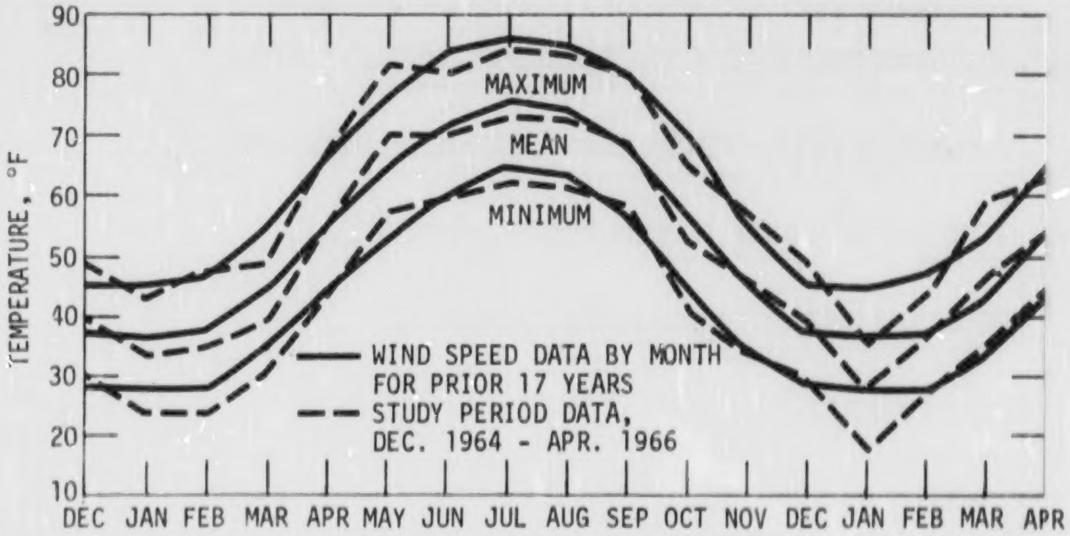


Figure 2-21. Average and study period monthly temperature variations at Kanawha Airport.

Bar-graphs of monthly precipitation amounts (Figure 2-22) and frequency (Figure 2-23) indicate less than normal rainfall for the summer of 1965 and fewer days with rain. July should have been the wettest month of the year. Showers, though frequent, were lighter than normal for July that year. Although the year 1965 had the normal number of days with rain, rainfall was less than normal. Rainfall in fall and winter of 1966 was also less than normal in both frequency and amount.

Occurrence of fog was nearly normal during the study, although fog was recorded more frequently than normal a few days during the summer of 1965, as shown in Figure 2-24.

Except for the possible effect of the two very dry periods, the weather during the study period was reasonably representative of the usual weather of the Kanawha Valley. This study covered periods of wet and dry conditions, warm and cold, windy and calm, with stable and unstable air.

SUMMARY

The nocturnal wind pattern within the Kanawha Valley is of primary concern in air pollution considerations. This flow of air is visualized as beginning at the shaded valley walls where the adjacent shallow layer of air cools with the ground and begins to slide downhill and to push beneath the warmer air over the valley floor. The air currents from opposite valley walls converge near the river and push

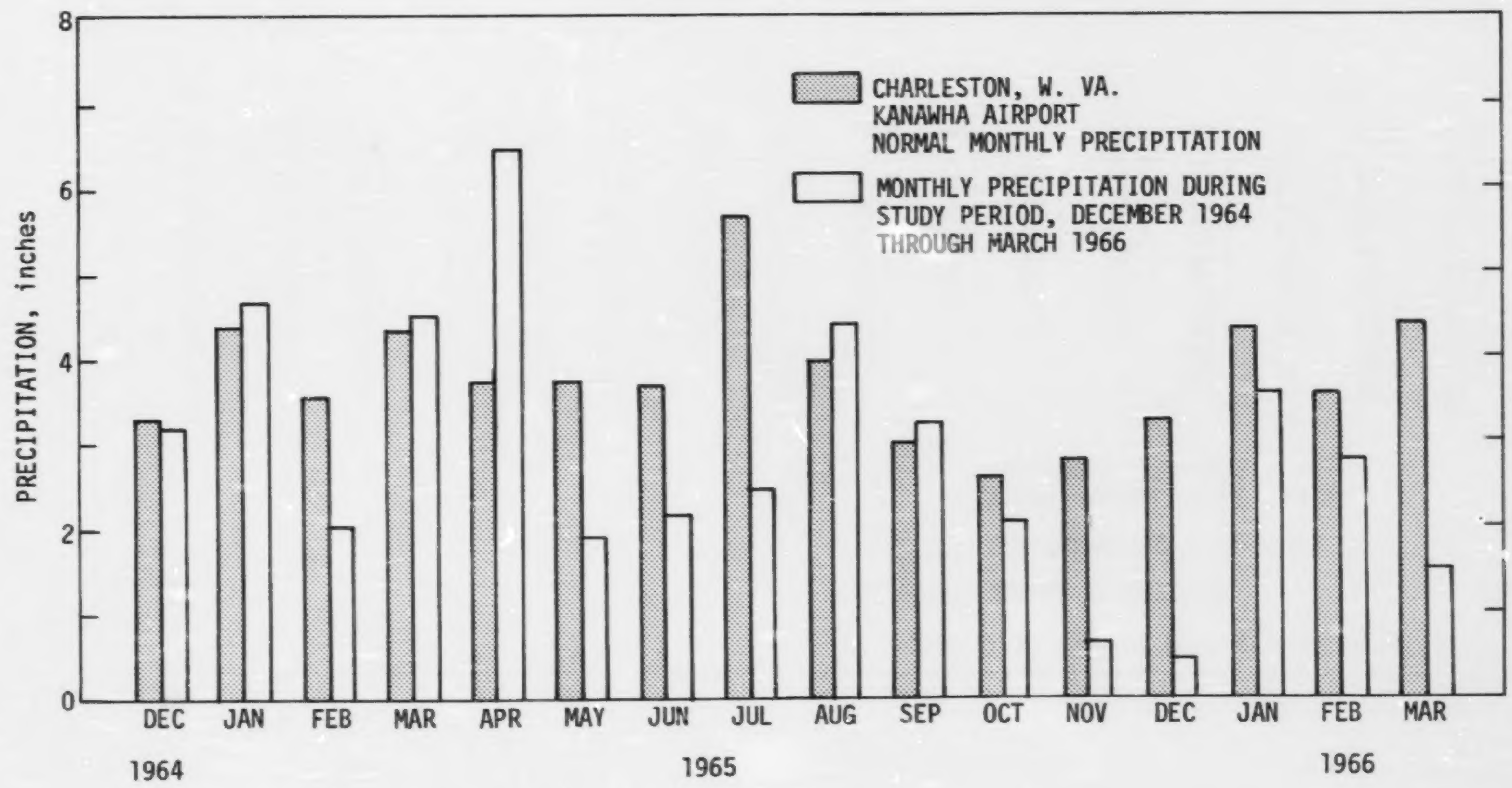


Figure 2-22. Normal and study period monthly precipitation at Kanawha Airport.

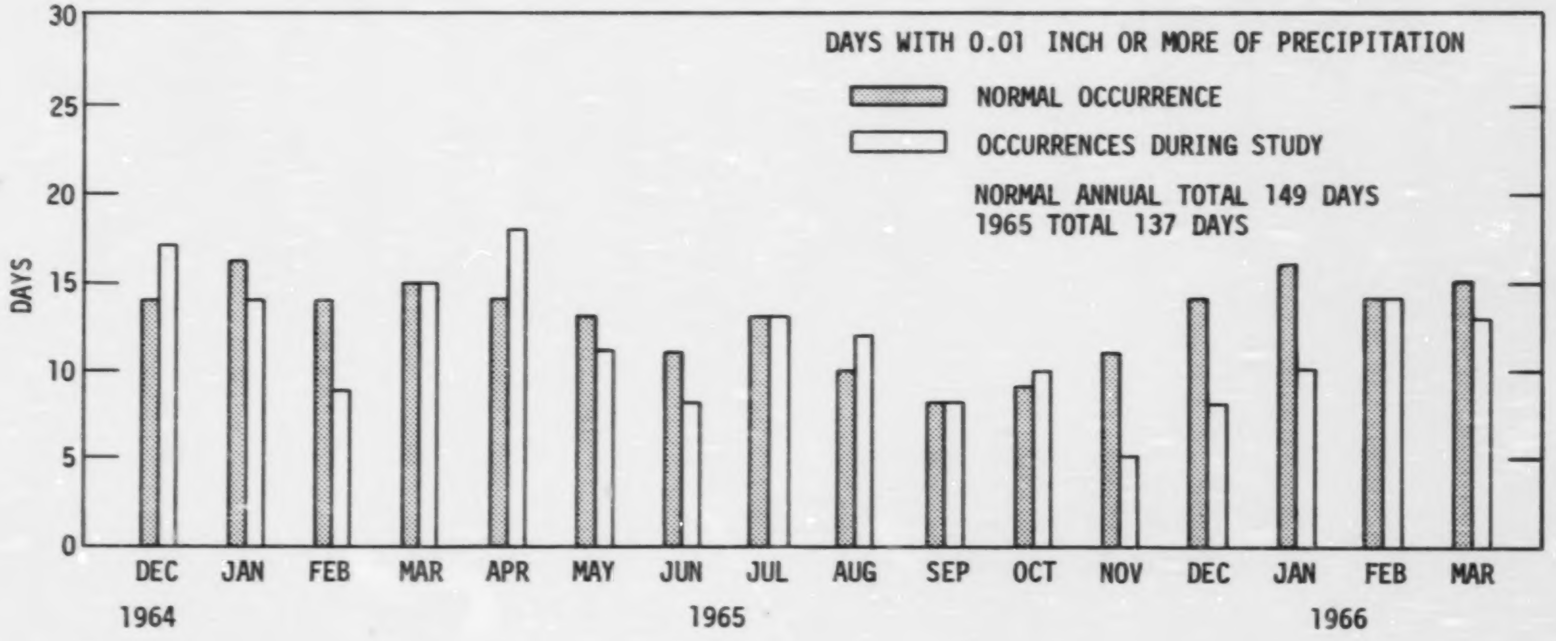


Figure 2-23. Normal and study period days with 0.01 inch or more of precipitation at Kanawha Airport.

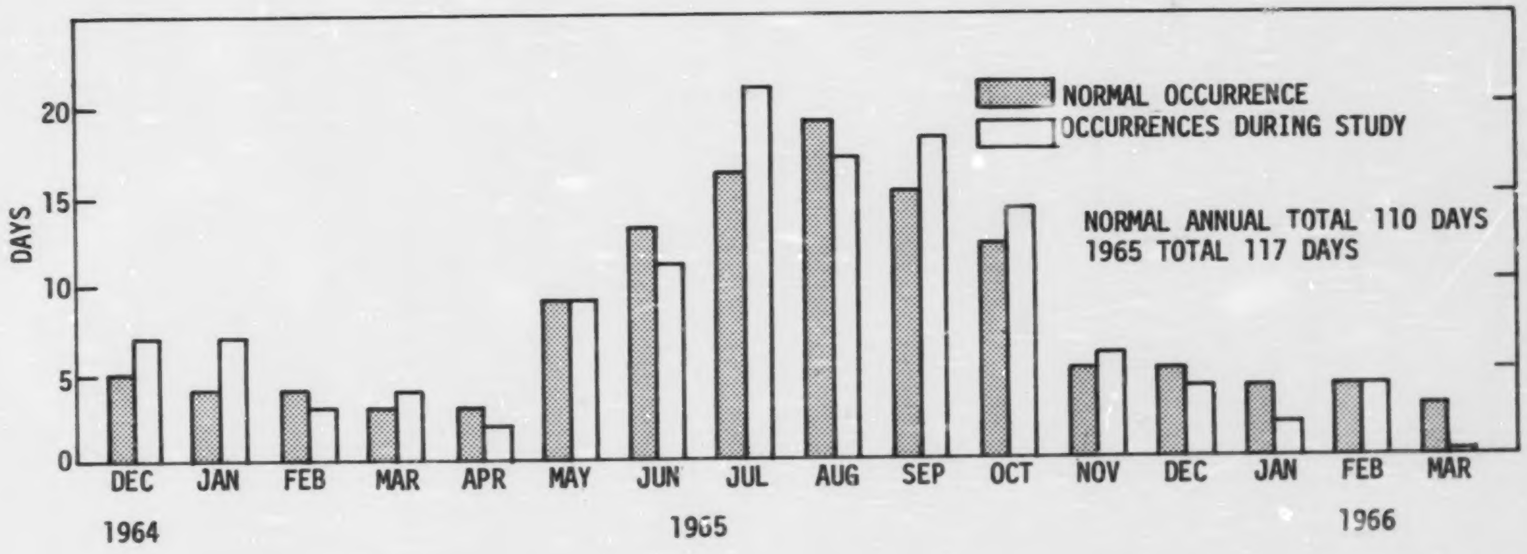


Figure 2-24. Normal and study period days with heavy fog (visibility of 1/4 mile or less) at Kanawha Airport.

the air up in this region. Heating from industrial processes and from the river water accents the natural upward air movement. The cool flow in the evening is at first only a few feet thick, and the air is replaced by slight lateral movement of air over the center of the valley. This lateral movement causes the emissions from all but the highest stacks to slowly mushroom to the valley walls as the pollutants drift within the stable air of the valley. As the flow becomes established and cooling continues, a downvalley component develops in the lower levels and a less pronounced upvalley tendency may be found in the return flow aloft. The net result is a thick blanket of polluted air that extends from one wall to the other at slightly above emission height on approximately half of the mornings of the year. On a typical night the blanket aloft drifts downvalley at 3 to 5 mph. The lowest layer of air is relatively clean, being a mixture from the valley proper and from feeder valleys with less industrial air pollution wastes. The valley experiences this type of temperature inversion during 66 percent of the hours of the year.

At sunrise the valley's floor and east facing slopes begin to warm and vertical currents are initiated as the warmed air seeks an equal density level. Adjacent cool air descends to form numerous "convective cells" at random over the valley floor. When these cells reach into the polluted layer that have collected above during the night, abrupt increases in visible pollutants and odors are noted on the valley floor and may appear to arrive from any compass direction. Because of the meandering character of the valley and the lack of a well-defined sunny plain at its mouth, the afternoon upvalley wind[11] is not well developed and is not a significant factor in air transport of the Kanawha Valley.

Typically, the daytime flow is determined by the general circulation above the highest hills in the area. In sections of the valley with steep high side-walls the flow is channeled to a marked degree along the valley's axis and may in fact be always one of two opposite directions. Wind speed within the valley is frequently only half of that above the valley and is subject to abrupt changes during the daytime as the flow aloft momentarily entrains air from the valley floor. Table 2-1 indicates average valley wind speed of 5.6 mph in winter and 3.7 in summer compared with hilltop values of 7.0 and 5.3, respectively.

The valley usually experiences the best ventilation of the day during the afternoon when relatively strong winds are apt to blow across the valley and bring fresh air into the area. Additionally, the daily maximum temperature and maximum temperature difference between valley rim and floor are experienced between 2 and 4 p.m., so that instability is greatest in the afternoon on normal days. Suspended particulate data (soiling) as measured by the AISI (American Iron and Steel Institute) tape sampler from the 14 stations monitored during the study reveal that minimum concentrations were recorded at either 2 or 4 p.m. in practically all cases.

Both pyrheliometer and sun photometer data indicate a sharp loss of solar radiation within the valley. This reduction is attributed to the particulate matter suspended in the air of the valley. High turbidity values found in Charleston decreases both upriver in eastern Kanawha City and downriver below Blaine Island. Rapid clearing is apparent in feeder valleys such as Elk and Davis Creek as well as outside the valley at the airport. If personnel had been available to take simultaneous sun photometer readings in all parts of the 50 miles of valley under study, local increases in turbidity would probably have been found in the vicinity of each major industrial complex.

Stable air was found to dominate the valley two-thirds of the hours of the year with at least a 60-foot-deep inversion being recorded at the Federal Building on over 90 percent of the sunrises. On most nights an inversion quickly builds to the valley rim or above and persists until well after sunrise. Breakup begins with a shallow heated layer on the valley floor mixing into a few feet of air above this layer. As heating and mixing continue, the air within the valley becomes essentially adiabatic 2 or 3 hours after sunrise, depending on such factors as cloud cover, wind speed and direction, and season. Particulate data indicate that vertical mixing reaches into the heavy concentrations of the suspended particulate aloft by 6 or 8 a.m., and results in the highest particulate values of the day being recorded at the ground in that period. Values for 6 and 8 a.m. are about double the 2 and 4 p.m. AISI tape sampler readings.

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SECTION III.
EMISSION INVENTORY

INTRODUCTION

A knowledge of the sources of air pollution in a community and an inventory of the quantities of air contaminants emitted by these sources are useful for successful air pollution control activities. An emission inventory provides data on the relative contributions of pollutants from various industrial processes, waste disposal practices, transportation, electric power generation, and the many other of man's day-to-day activities. This inventory also reveals the geographical distribution of the various types of pollutants emitted in the study area. From the data gathered in the emission inventory, better judgments can be made in air pollution control with respect to urban planning, air sampling programs, emission control activities, and the impact of further population and industrial expansion.

In the recent Kanawha Valley Study, data on fuel consumption, materials processed, and waste material disposal were ascertained through the various methods discussed below. Quantities of pollutants emitted were then determined primarily through two mechanisms: (1) Application of published emission factors (see Appendix C) derived from stack tests on similar processes, or (2) in some cases, review and evaluation of emission data provided by the management of the inventoried sources.

For the purposes of this report all emissions are summarized under the following general source categories:

1. Fuel combustion.
2. Industrial processes.
3. Refuse disposal.
4. Miscellaneous

These major classifications are further subdivided for tabular presentation. Fuel combustion includes utility power generation; industrial power and steam generation; residential, commercial, and institutional heating; and transportation. Industrial processes include chemical production, metallurgical operations, mining and coal preparation, asphaltic and concrete mix plants, and other manufacturing operations. Refuse disposal includes open burning dumps, backyard burning, and incineration. Miscellaneous includes solvent and gasoline evaporation, and sewage treatment plants.

Each of the above source classifications in presented in terms of its contribution to particulate, inorganic gaseous, and organic gaseous pollutants. Some major pollutants are also presented on an individual area basis. Locations of major industrial sources are shown in Figure 3-1.

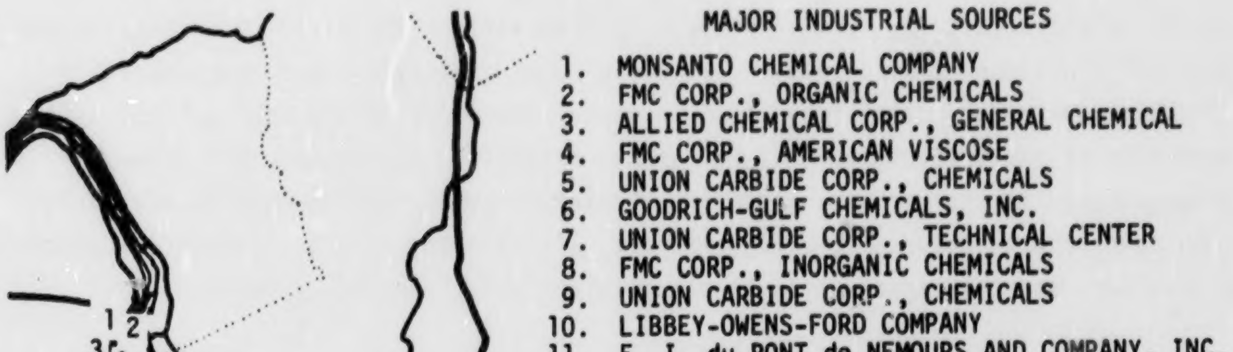
MAJOR INDUSTRIAL SOURCES
1. MONSANTO CHEMICAL COMPANY
2. FMC CORP., ORGANIC CHEMICALS
3. ALLIED CHEMICAL CORP., GENERAL CHEMICAL
4. FMC CORP., AMERICAN VISCOSE
5. UNION CARBIDE CORP., CHEMICALS
6. GOODRICH-GULF CHEMICALS, INC.
7. UNION CARBIDE CORP., TECHNICAL CENTER
8. FMC CORP., INORGANIC CHEMICALS
9. UNION CARBIDE CORP., CHEMICALS
10. LIBBEY-OWENS-FORD COMPANY
11. E. I. du PONT de NEMOURS AND COMPANY, INC.
12. DIAMOND SHAMROCK COMPANY
13. APPALACHIAN POWER COMPANY
14. APPALACHIAN POWER COMPANY
15. UNION CARBIDE CORP., METALS
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Figure 3-1. Location of major industrial sources in Kanawha Valley.

EMISSION FROM FUEL COMBUSTION

Utility and Industrial Power and Steam Generation Methodology

A list of major utility and industrial heat- and power-generation facilities was compiled, and questionnaires (see Appendix C) requesting information on firing methods, fuel used, ash, emission controls, etc. were sent to the management of each facility. All 13 plants queried returned the questionnaire. The completed questionnaires were then subjected to an engineering evaluation to determine thoroughness and apparent accuracy. The engineering evaluation was followed by a plant visit for further review and familiarization with individual installations.

A listing of other relatively smaller industrial plants was obtained either from the West Virginia Manufacturing Directory,[1] or from telephone directories. Plants considered to be probable sources of process emissions were sent questionnaires, and those not considered to be sources of process emissions were contacted by telephone. Information was requested on the type and amount of fuel burned and the method of combustion. If the telephone survey showed that an installation also burned coal, a questionnaire was sent to the plant. Natural gas consumption for the remaining units was ascertained from the gas suppliers.[2]

Results - Two utility plants of the Appalachian Power Company are located in the study area - the Kanawha River Station at Glasgow and the Cabin Creek Plant at Cabin Creek. At the time of the inventory, both plants used pulverized coal firing in their six boiler furnaces and in 1964 consumed 1,441,020 tons of bituminous coal.

The Kanawha Station operates at a constant loading, whereas the Cabin Creek Plant, during the time the inventory was in preparation, provided power during peak periods and normally operated 5 days per week for approximately 10 hours per day. Since completion of the inventory, however, increased power demands have necessitated the Cabin Creek Plant to reactivate boilers that were not being used during the inventory. The pollutants emitted from these additional boilers are not included in the inventory.

There are 11 large industrial steam-generation plants located in the study area. The plants and respective locations are: Union Carbide Corporation, Metals Division, Alloy; E.I. du Pont, Belle; Union Carbide Corporation, Chemicals Division, with two boiler plants each at South Charleston and Institute; Union Carbide Corporation, Technical Center, South Charleston; FMC Corporation, Inorganic Chemicals Division, South Charleston; Goodrich-Gulf Chemicals, Incorporated, Institute, FMC Corporation, American Viscose Division, Nitro; and Monsanto Chemical Company, Nitro.

These major industrial steam-generating plants operate a total of 78 boiler furnaces, which burned 3,148,855 tons of coal, 9,955 million cubic feet of natural gas, and 41,003,000 gallons of oil and chemical process residues in 1964. The overall particulate control efficiency was reported to be 71 percent; individual industrial plant efficiencies varied from 0 percent (or no control) to 96 plus percent efficiency. Where oil and chemical waste residues were used as boiler fuel, emissions were determined using emission factors for Number 2 fuel oil. This assumption probably results in some error in reported emissions; but the emission factors for Number 2 oil appear to be applicable because the residues were reported by plant personnel to be light hydrocarbon fractions and relatively free of sulfur and other contaminants.

Total coal consumption reported for the 84 major utility and industrial boiler furnaces on stream during the inventory was 4,589,875 tons per year. A weighted average of the ash reported was 11.74 percent, with a range from 6.5 to 16.0 percent. The weighted average sulfur content of the coal burned in 1964 with 0.95 percent, with a range from 0.7 to 1.7 percent.

The smaller industrial installations consumed 3,608 tons of coal and 4,026 million cubic feet of natural gas in 1964.

Table 3-1 presents a summary of fuel consumption and particulate emission for utility plants as well as large and small industrial installations. Tables 3-2 and 3-3 present inorganic and organic gaseous emissions, respectively. Emission factors used for coal, natural gas, and oil are listed in Appendix C.

Examination of the effects of seasonal variation of these major installations revealed that the average variation in steam load was about 10 percent. Seasonal variations in emissions are shown in Table 3-3A.

Residential, Institutional, and Commercial Heating Fuel Methodology

Fuel data for all commercial establishments and institutions were obtained by telephone, by questionnaires, or from knowledgeable public officials, such as fire chiefs, health officers, and county school officials. Commercial and institutional sources contacted by telephone were apartment buildings, automobile agencies, banks, wholesale bakeries, department and drug stores, hotels, retail lumber companies, greenhouses, motels, motor freight lines, equipment companies, supermarkets, office buildings, railroads, schools; and local, state, and federal agencies. Questionnaires were sent to those who indicated by telephone that fuels other than natural gas were used. Natural gas consumption data were obtained from the gas companies.[2]

Table 3-1. ESTIMATED PARTICULATE EMISSIONS FROM FUEL COMBUSTION SOURCES

			Estimated particulate emissions					
			Potential emissions		Actual emissions			
Source classification	Fuel type	Fuel used	tons/day	Percent	tons/yr	tons/day	Percent	Percent control
Steam and heat generation								
Utility	Coal	1,441,020.0[a]	372.2	29.7	15,512.5	42.5	14.0	88.5
Large and small industrial	Coal	3,152,463.0[a]	878.4	70.0	93,440.0	256.0	84.6	70.8
	Natural gas	13,980.7[b]	0.3	Neg[c]	109.5	0.3	0.1	0.0
	Oil and residue	41,002.6[d]	0.2	Neg	73.0	0.2	Neg	0.0
Commercial, Institutional, and residential	Oil	250.4[d]	Neg	Neg	Neg	Neg	Neg	0.0
	Coal	11,094.2[a]	0.3	Neg	109.5	0.3	0.1	0.0
	Natural gas	11,439.2[b]	0.4	Neg	146.0	0.4	0.1	0.0
Subtotal			1,251.8	99.7	109,390.5	299.7	98.9	76.0[f]
Transportation								
Road vehicles	Gasoline	60,119.3[d]	0.9	Neg	328.5	0.9	0.3	0.0
Road vehicles	Diesel fuel	9,356.8[d]	1.4	0.1	511.0	1.4	0.5	0.0
Railway	Diesel fuel	3,433.0[d]	0.5	Neg	182.5	0.5	0.2	0.0
Vessels	Diesel fuel	1,218.0[d]	0.2	Neg	73.0	0.2	Neg	0.0
Aircraft	Gasoline	42,967.0[e]	Neg	Neg	Neg	Neg	Neg	0.0
Subtotal			3.0	0.2	1,095.0	3.0	1.0	0.0
Overall totals			1,254.8	99.9	110,485.5	302.7	99.9	75.9[f]

[a] Tons per year.

[b] Million cubic feet per year.

[c] Neg. - Negligible.

[d] Thousand gallons per year.

[e] Flights per year.

[f] Weighted average.

Table 3-2. ESTIMATED INORGANIC GASEOUS EMISSIONS FROM FUEL COMBUSTION

Source classification	Fuel type	Fuel used	Sulfur oxides		Nitrogen oxide		Carbon monoxide	
			tons/yr	percent	tons/yr	percent	tons/yr	percent
Steam and heat generation								
Utility	Coal	1,441,020^{a}	27,320	32.0	14,410	26.3	360	0.4
Large and small industrial	Coal	3,152,463.0^{a}	55,714	65.2	31,525	57.6	4,728	Neg^{b}
	Natural gas	13,980.7^{c}	2.8	Neg	1,496	2.7	2.8	Neg
	Oil and residue	41,002.6^{d}	1,609	1.9	1,476	2.7	41	Neg
Commercial, institutional, and residential	Oil	250.4^{d}	20	Neg	9	Neg	0.2	Neg
	Coal	11,094.2^{a}	202	0.2	44	0.1	277	0.3
	Natural gas	11,439.2^{c}	2	Neg	663	1.2	2	Neg
Subtotal			84,869.8	99.3	49,623.0	90.6	5,411.0	5.6
Transportation								
Road vehicles	Gasoline	60,119.3^{d}	270	0.3	3,397	6.2	87,474	91.0
Road vehicles	Diesel fuel	9,356.8^{d}	187	0.2	1,039	1.9	281	0.3
Railways	Diesel fuel	3,433.0^{d}	69	0.1	381	0.7	103	0.1
Vessels	Diesel fuel	1,218.0^{d}	24	Neg	135	0.2	36	Neg
Aircraft	Gasoline	42,967.0^{e}		n.a.^{f}	171	0.3	2,826	2.9
Subtotal			530	0.6	5,123	9.3	90,720.0	94.3
Overall totals			85,399.8	99.9	54,746.0	99.9	96,131.0	99.9

[a] Tons per year.

[b] Neg. - Negligible.

[c] Million cubic feet per year.

[d] Thousand gallons per year.

[e] Flights per year.

[f] n.a. - Not available.

Table 3-3. ESTIMATED ORGANIC GASEOUS EMISSIONS FROM FUEL COMBUSTION

Source classification	Fuel type	Fuel used	Hydrocarbons		Aldehydes		Organic acids	
			tons/yr	percent	tons/yr	percent	tons/yr	percent
Steam and heat generation								
Utility	Coal	1,441,020.0[a]	144	0.7	4	1.5	n.a.[b]	
Large and small industrial	Coal	3,152,463.0[a]	1,576	8.1	8	3.0	n.a.	
	Natural gas	13,980.7[c]	Neg[d]		14	5.3	434	38.5
	Oil and residue	41,002.6[e]	41	0.2	41	15.6	n.a.	
Commercial, institutional, and residential	Oil	250.4[e]	0.2	Neg	0.2	0.1	n.a.	
	Coal	11,094.2[a]	56	0.3	0.3	0.1	n.a.	
	Natural gas	11,439.2c	Neg	Neg	Neg	Neg	355	31.5
Subtotal			1,817.2	9.3	67.5	25.6	789.0	70.0
Transportation								
Road vehicles	Gasoline	60,119.3[e]	15,751	81.2	120	45.5	120	10.7
Road vehicles	Diesel fuel	9,356.8[e]	842	4.3	47	17.8	145	12.9
Railways	Diesel fuel	3,433.0[e]	309	1.6	17	6.5	53	4.7
Vessels	Diesel fuel	1,218.0[e]	110	0.6	6	2.3	19	1.7
Aircraft	Gasoline	42,967.0[f]	568	2.9	6	2.3	n.a	
Subtotal			17,580	90.6	196.0	74.4	337.0	30.0
Overall Totals			19,397.2	99.9	263.5	100.0	1,126.0	100.0

[a] Tons per year.

[b] n.a. - Not available.

[c] Million cubic feet per year.

[d] Neg. - Negligible.

[e] Thousand gallons per year.

[f] Flights per year.

Table 3-3A. SEASONAL VARIATION IN FUEL COMSUMPTION
(10^6 Btu)

Fuel	Winter	Spring	Summer	Fall	Total
Coal[a]	31,045,300	29,866,200	28,831,200	29,955,800	119,698,500
Natural gas[b]	9,797,200	5,369,800	3,921,300	6,500,800	25,589,100
Oil organic liquid wastes[c]	1,526,100	1,438,600	1,363,800	1,447,000	5,775,500
Totals	42,368,600	36,674,600	34,116,300	37,903,600	151,063,100

[a] Coal - 26 x 10^6 Btu/ton.

[b] Natural gas - 1,000 Btu/ft^3.

[c] Oil or organic liquid wastes - 140,000 Btu/gal.

Most of the other consumers not contacted by the telephone survey were assumed to burn natural gas.

Residential gas consumption information was obtained from data furnished by the gas companies, and coal combustion information was taken from the 1960 census report for the State of West Virginia.[3] The census data were used to estimate the number of residences burning fuels other than natural gas in areas of Kanawha County situated in the study area. Information furnished by the natural gas companies, plus census data, were used to estimate the number of Fayette and Putnam County residences within the study area that burned coal and oil for heat. These estimates indicated that 95 percent of the homes in the study area used natural gas as a fuel, and 2.5 percent of the homes burned coal. These estimates were used as a basis for determining fuel consumption for both Fayette and Putnam counties. The total number of degree-days for 1964 for the Charleston area was obtained from Weather Bureau reports[4] and was used for the entire study area. Fuel consumption in residences was calculated using a method developed by the U.S. Public Health Service (see Appendix C). All coal burned in residences was assumed to be hand-fired. Emissions from liquefied petroleum gases, calculated from emission factors for natural gas, were found to be negligible. Refer to Tables 3-1, 3-2, and 3-3 for fuel consumption, particulate, and gaseous emissions, respectively.

Results - Space heating for commercial, institutional, and residential installations accounted for only about 0.2 percent of the total particulates emitted from all fuel combustion. The total emissions of inorganic and organic gaseous pollutants were also insignificant.

Because of the large percentage of home heating by relatively clean burning natural gas, the seasonal pollutant variation was negligible, see Table 3-3A.

Transportation

Methodology - All data on fuel consumption for highway vehicles were obtained from the West Virginia State Gasoline Tax Division. For tax purposes, these data were divided into two main categories: (1) Total fuel usage in gallons per month for statewide motor carriers (trucks, buses, etc., located in the study area), and (2) county retail service station gasoline and diesel fuel deliveries in gallons per month.

Tax Division estimates indicated that 60 percent of the fuel used by motor carriers was diesel and the remainder, gasoline. Although the data for motor carriers represented fuel purchased and used in the State, it was assumed for the calculation of exhaust emissions, that all fuel reported was consumed within the study area. Fuels consumed by local motor carriers outside the study area were assumed to be offset by the fuel consumption within the valley by those motor carriers located outside the study area.

All fuel delivered to retail stations in Kanawha, Fayette, and Putnam Counties was assumed to be ultimately consumed within these counties. State Road Commission traffic data were used to estimate, from county retail gasoline and diesel sales, the amount of fuel consumed by motor vehicles in the study area.

Diesel fuel consumption data for railways were supplied by the railroad companies.[5] The U.S. Army Corps of Engineers, Huntington District, and barge operating companies[6] supplied data on fuel consumption of diesel-powered vessels. Data on flights from the Kanawha County Airport were supplied by the Federal Aviation Agency.

Results - Fuel consumption in 1964 for all ground and water sources was estimated to be 60,119,300 gallons of gasoline and 9,356,800 gallons of diesel fuel. The number of aircraft flights for 1964 was reported to be 42,967.

Emissions from these sources were estimated from the appropriate emission factors found in Appendix C. The results are reported in Tables 3-1, 3-2, and 3-3. As would be expected, transportation sources accounted for the highest percentage of carbon monoxide emissions (89 percent.) Hydrocarbon losses by evaporation are not reported in Table 3-3; they are discussed in the section on evaporation losses.

Seasonal variation of emissions from gasoline consumed by motor vehicles is reported in Table 3-3B.

Table 3-3B. SEASONAL VARIATION OF EMISSIONS FROM GASOLINE COMBUSTION (tons)

Pollutant	Summer	Fall	Winter	Spring
Carbon monoxide	23,385	21,240	20,111	22,738
Hydrocarbons	4,203	3,817	3,614	4,087
Nitrogen oxides	908	825	781	883
Sulfur oxides	72	66	62	70
Aldehydes	32	29	28	31
Organic acids	32	29	28	31
Ammonia	16	15	14	16
Particulates	88	80	76	86

EMISSIONS FROM INDUSTRIAL PROCESS

The study area is one of the Nation's largest basic chemical production complexes. Located within the valley are eight major chemical plants, plus viscose rayon, synthetic rubber, electro-metallurgical, flat glass, military vehicle, and railroad car manufacturing plants. Also included in this source category are coal mining and preparation plants, asphalt hot-mix plants, and numerous small chemical, manufacturing, and fabrication installations. The emissions from these sources are varied and complex and, in some cases, unknown.

General Methodology

The information required for the inventory of process emissions was obtained by both questionnaires (see Appendix C) and personal contact with all the industrial plants and commercial establishments that were considered to be probable sources of process air pollution emissions. Information was requested on products, types of process equipment and operations, and air pollution emissions and control equipment. Where questions arose or additional information was required, the plants or establishments were contacted and the information was obtained either by telephone or by site visits.

The questionnaire response from the major plants was excellent, with a 100 percent return. The response from the other plants and commercial establishments was good, with a 67 percent return from the smaller industrial plants and a 48 percent return from the commercial establishments, with one follow-up.

Chemical Processes

Methodology - The questionnaire used to obtain information from the chemical process industries was developed jointly by the study staff and representatives of these plants. The process emissions reported were reviewed with company personnel responsible for the completion of the questionnaire, and the completed questionnaires were revised when more accurate or current information became available.

The process section of the questionnaire was divided into six parts: (1) Principal products; (2) specific material emitted to the atmosphere; (3) organic and inorganic materials emitted and not reported in the second part; (4) types of furnaces used; (5) other equipment or operation including air blowing, dryers, kilns, solids handling and processing; and (6) air pollution control equipment used in process operations. The completed questionnaires, coupled with plant visits, provided sufficient information to make useful estimates as to the contribution to air pollution by the chemical industries. The responses varied from a detailed reporting of emissions, products, and control equipment to returns with more general information.

Emission factors and published information on emissions or losses from chemical processes are limited, principally because of the large number of products, great variety of processes used to manufacture these chemical products, and lack of stack emission measurements. Also, the data and information necessary to develop emission factors are usually considered by the chemical industries to be proprietary information. Because of the lack of emission factors and information on losses from chemical processes located in the valley, the process emission data presented are principally those provided by the completed questionnaire.

Results - The major sources of process emissions in the Kanawha Valley are the chemical industries (Table 3-4). Also included in this classification are the viscose rayon and the synthetic rubber plants. These plants range in size from large complexes having several thousand employees and making hundreds of products - in some instances producing hundreds of tons daily - down to a fine-chemicals plant, employing less than 100 men and making products in the 5- to 10-pound range. Emissions from these plants are varied and include organic compounds ranging from simple hydrocarbons to compounds with complex molecular structures. Particulates, consisting principally of acid mists, are emitted, as well as gases such as sulfur oxides, nitrogen oxides, carbon disulfide, hydrogen sulfide, carbon monoxide, and, possibly, numerous others which were not identified.

Table 3-4. ESTIMATED EMISSIONS FROM INDUSTRIAL PROCESSES

Source class	Total particulate		Sulfur oxides, tons/yr	Nitrogen oxides, tons/yr	Carbon monoxide, tons/yr	Ammonia, tons/yr	Hydro-carbons, tons/yr	Organic compounds,[a] tons/yr	Organic acids, tons/yr	Alde-hydes, tons/yr
	tons/day	tons/yr								
Chemicals	26.8[b]	9,782[b]	24,150	1,240	6,120	600	17,764	32,205	293	907
Metallurgical	21.7	7,920	c	c	c	c	d		c	c
Glass and ceramics	1.2	438	c	c	c	c	d		c	c
Hot asphalt mix plants	0.7	256					c		c	c
Concrete batch plants	0.2	73								
Lumber and wood	0.2	73	0.5	0.4	c	c	50.5		1.2	5.4
Fabrication	0.2	73					d			
Total	51.0	18,618	24,150	1,240	6,120	600	17,814	32,205	294	912

[a] Includes all organic compounds except hydrocarbons, organic acids, and aldehydes.

[b] Includes acid mist.

[c] Not reported or unavailable.

[d] Included in solvent evaporation losses.

Chemical processes in the study area were estimated to be responsible for emitting approximately 56 percent of the hydrocarbons,* 7 percent of the particulates, 22 percent of the sulfur oxides, 6 percent of the carbon monoxide, 2 percent of the nitrogen oxides, 30 percent of the organic acids, 65 percent of the aldehydes, and 78 percent of the ammonia (Table 3-4). These emissions are divided into four classifications - organic gaseous, organic particulate (Table 3-5), inorganic gaseous, and inorganic particulate (Table 3-6). The organic gaseous emissions listed are reported to be principally in the two- to six-carbon atom range.

Table 3-5 lists the large amounts of acids, alcohols, aldehydes, amines, ketones, and esters, which are emitted to the atmosphere. These compounds, plus large amounts of hydrogen sulfide, and other organic sulfur compounds including carbon disulfide, probably cause a major part of odor problems in the study area. These organic compounds could possibly cause some of the complaints of irritation of the eyes, nose, and throat.[7] The 22.6 tons per day of acid mist emissions probably causes materials deterioration[8,9] and also contributes to the reported incidents of nose and throat irritations.[9]

Table 3-5. ESTIMATED ORGANIC EMISSIONS FROM CHEMICAL AND RELATED PROCESSES

Chemical Classification	Gaseous emissions		Particulate emissions	
	Tons/yr	Percent	Tons/yr	Percent
Hydrocarbons	17,764	34.7	542	42.1
Alcohols	3,723	7.3	-	
Aldehydes	907	1.8	-	
Amines	411	0.8	480	37.2
Acids	293	0.6	153	11.9
Ethers	2,767	5.4	-	
Epoxides	1,066	2.1	-	
Halides	5,928	11.6	108	8.4
Ketones	2,382	4.7	-	
Acid derivatives	183	0.4	5	0.4
Sulfur compounds	14,408	28.2	-	
Esters	89	0.2	-	
Nitrogen compounds	62	0.1	-	
Unclassified	1,186	2.3	-	
Totals	51,169	100.0	1,288	100.0

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*Includes all organic compounds, except aldehydes and organic acids.

Table 3-6. ESTIMATED INORGANIC EMISSIONS FROM CHEMICAL AND RELATED PROCESSES

Chemical compounds or classifications	Gaseous emissions tons/yr	Gaseous emissions percent	Chemical compounds or classifications	Particulate emissions tons/yr	Particulate emissions percent
Sulfur dioxide	24,146	65.9	Sulfuric acid	5,348	63.0
Ammonia	600	1.6	Hydrochloric acid	2,646	31.2
Chlorine	73	0.2	Nitric acid	292	3.4
Carbon monoxide	6,120	16.7	Sulfur	73	0.9
Nitrogen oxides	1,241	3.4	Calcium fluoride	55	0.7
Hydrogen	1,150	3.1	Sodium sulfate	4	0.1
Cyanide compounds	13	Neg[a]	Sulfur monochloride	37	0.4
Hydrogen fluoride	Trace[b]	Neg	Sulfur dichloride	2	Neg
Hydrogen sulfide	3,322	9.1	Aluminum chloride	16	0.2
			Hydroxides	2	Neg
			Miscellaneous	9	0.1
Totals	36,665	100.0		8,484	100.0

[a] Negligible.

[b] Trace.

Methods or equipment reported to be used to control these emissions range from fabric filters, with efficiencies up to 99.5 percent, to absorbers, with one having a reported efficiency as low as 10 percent. The process control equipment reported by the chemical plants, including ranges of efficiencies, number of installations, and miscellaneous equipment that does not fit in the usual equipment categories, is presented in Table 3-7. This control equipment is listed in the table under the categories selected by the industrial representatives responsible for completion of their questionnaires.

Air pollution control devices, especially in the chemical process industries, are difficult to separate from equipment used for product recovery. Equipment such as condensers and absorption columns, when used primarily for product recovery or for the collection and reuse of intermediates, are often overdesigned, and thus reduce emissions to the atmosphere. This type of equipment is not reported in Table 3-7. The study staff did not attempt to determine what percent of the collection efficiency or which portion of the product recovery equipment is used for air pollution control since this would be most difficult and time consuming.

Table 3-7. EQUIPMENT UTILIZED BY MAJOR INDUSTRIAL PLANTS IN KANAWHA VALLEY TO CONTROL AIR POLLUTION FROM PROCESS OPERATIONS

Equipment classification	Number of units reported	Range of reported efficiencies, percent
Fabric filters	95	98 to 99.5+
Absorption units	19	10 to 99
Direct-fired afterburners	15	80 to 100
Catalytic afterburners	2	99 to 100
Demister	10	(Unknown)
Adsorption units	14	90 to 99
Scrubbers	67	50 to 100
Cyclones	39	59 to 99
Multicyclones	15	80 to 90
Other inertial separators	4	(Unknown)
Vapor recovery systems	27	(Unknown)
Boilers	7	(Unknown)
Condensers	14	0 to 99.5
Other - such as tall stacks,[a] settling chambers, hydrogen sulfide recovery (sulfur), neutralization pits, floating roof tanks, inert gas vent, vacuum systems.	38	0 to 100

[a] Reported as a method of control of air pollution.

Metallurgical Processes

Methodology - The reported emissions from a large electrometallurgical plant located at Alloy, a lead oxide plant in Charleston, and several small metallurgical plants located in the study area were essentially all particulate. These emissions were either reported on the questionnaire or were determined by means of published emission factors (see Appendix C).

Results - The estimated particulate emissions from metallurgical processes (Table 3-4) were 21.7 tons per day, or approximately 6.0 percent of the overall particulate emissions. The predominate emissions were silicates and metal oxides. No gaseous emissions were reported or estimated, though carbon monoxide, nitrogen oxides, sulfur oxides, and other gaseous compounds are probably released into the atmosphere from some of these operations. Gaseous emissions from combustion were determined and are presented in the section on fuel combustion.

The control equipment listed by the companies includes fabric filters, scrubbers, and settling chambers. Some of the installations or furnaces do not have control devices. The reported efficiencies of the installed control equipment range from 98 to 99.5 percent for the fabric filters to approximately 90 percent for the scrubbers. The size and complexity of the process and control equipment and operations vary greatly.

Glass and Ceramic Processes

Methodology - A large flat-glass plant in Kanawha City, a small glass plant, a cement storage facility, and several brick and building block manufacturing plants are located in the study area. The particulate emissions were determined by the use of either emission factors or engineering estimates. Gaseous emission data from these process sources were not available, either from a materials balance or by use of emission factors.

Results - The estimated particulate emissions from these processes, as reported in Table 3-4, were 1.2 tons per day, or approximately 0.3 percent of the overall particulate emissions and 2.4 percent of the process particulate emissions. Gaseous emissions were determined for products of combustion from the heating of the glass and the firing of the bricks and blocks. These emissions are included in the discussion of industrial natural gas consumption in the fuel combustion section of this report.

The control equipment reported by these plants ranges from fabric filters at 99 plus percent efficiency to cyclones with unknown efficiencies. Many installations reported no controls. Also, the size, complexity, and type of operations varied considerably, as would be expected from such diverse sources.

Hot Asphalt Mix Plants

Methodology - The asphalt mix plants located in the study area reported either emissions or production information, which were used with published emission factors to estimate the emissions.

Results - Four asphalt mix plants reported emissions of 0.7 ton per day.

Multicyclones were reported to be installed on all units, and a wet scrubber in series with a multicyclone was reported in one plant. The efficiencies reported by these plants ranged from 80 to 85 percent for the multicyclones to 98 percent for the multicyclone in series with the wet scrubber. The plants varied in size and periods of operation, and also in the kinds of raw materials and types of equipment used.

Asphalt mix plants, when not properly controlled, cause serious local air pollution problems. These emissions normally do not effect large areas because of their low plant exhaust stacks - usually less than 50 feet in height - and the relatively large particle size of most of the materials emitted into the atmosphere.

Concrete Batch Plants

Methodology - The concrete batch plants located in the Kanawha Valley reported production figures that were then used with published emission factors to estimate the emissions.

Results - The estimated emissions reported in Table 3-4 were 0.14 ton per day, less than 0.1 percent of the total particulate emissions. These emissions were calculated for plants having no control equipment, since no controls were reported.

Lumber and Wood Products

Methodology - Emissions from lumber and woodworking plants were either obtained from reported losses or calculated from production estimates (see Appendix C). Production data were estimated for a small number of wood processing plants that did not provide the information requested.

Results - The estimated emissions of 0.23 ton per day of particulates reported in Table 3-4 were mainly from the combustion of sawdust and wood waste. The emissions reported were sawdust from wood cutting and shaping operations, and combustion emissions from the burning of wood wastes.[10]

The only control devices listed were cyclone collectors with unreported collection efficiencies. The sawdust and wood waste were burned in single-chamber incinerators called "teepees," in open fires, or in boilers. These sources of pollution cause serious local nuisance problems because of the resulting smoke, odors, and dustfall (flyash and soot).

Coal Mining and Preparation Plants

Methodology - Since none of the coal companies located in the Kanawha Valley reported emissions from their operations, production information presented in the

1964 Annual Report of the West Virginia State Department of Mines was used to estimate the emissions from the coal preparation plant. Literature[11,12] indicates that losses from mineral processing can range from 0.1 to 1.0 percent of the material produced.

An emission factor of 0.1 percent of the coal produced was used to estimate the particulate emissions because the losses from coal preparation plants were considered to contribute little to the study area's air pollution levels. The losses from these plants are considered to be localized nuisances, due to the large particle size of the coal during processing, storage, and transportation. This assumption is supported by the lack of complaints of the effects of air pollution from this source by people in the study area. The absence of coal thermal driers at valley coal preparation plants also greatly reduces the air pollution potential of these sources.

Results - Particulate emissions from coal mining and preparation were estimated to be 33.6 tons per day. Since these emissions were considered to be causing a dust problem restricted to the immediate area surrounding the plant and haulage routes, these losses were not included in the particulate emissions used to develop the suspended particulate emission reduction plan for the study area. Control methods reported consisted of fabric filters, scrubbers, and the use of oil and water sprays to reduce dust losses during handling and storage of materials.

Fabrication Plants

Methodology - Included with the fabrication plants are several machine shops. Emissions reported were mainly from cleaning with solvents or painting. The particulate emissions reported were considered to be insignificant. Where process operations listed on the completed questionnaires indicated potential sources of particulate emission with no method of control reported, the probable emissions were estimated.

Results - The emissions reported in Table 3-4 were estimated to be 0.17 ton per day of particulate and 17,752 gallons of solvent per year. The solvent emissions are included in the section of the report on solvent losses. Because not all of the plants reported their solvent losses, the reported figure is considered to be low.

Collection equipment reported ranged from fabric filters with an estimated 99 percent efficiency, down through settling chambers with a reported efficiency of 75 percent, to equipment with no control. The control equipment listed for these fabrication plants was solely for particulate emissions. No control equipment was reported for gaseous or solvent emissions.

EMISSIONS FROM REFUSE DISPOSAL

Methodology

All 13 incorporated municipalities and major industrial and utility sources in the study area were sent questionnaires (see Appendix C) requesting information on quantities and types of refuse and method of disposal. A telephone survey of small industrial and commercial facilities was made to help determine their method of refuse disposal. If this survey indicated that refuse disposal was accomplished by burning on the premises, a questionnaire was sent to that establishment to further investigate the quantities and types of refuse and method of burning. If questionnaires were not returned by municipalities or the information was questionable, a general figure of 1,000 pounds of combustible refuse per capita per year was applied to the number of residents to estimate total annual refuse production in the area. This amount was then broken down as to method of disposal according to current trends and previous knowledge of the area.

Examination of per capita quantities of combustible refuse in the literature[13,14,15,16] revealed a wide variation in reported data. These quantities are influenced by collection and disposal practices as well as geographical and seasonal variations. Since no rigorous study of these quantities had been conducted in the study area, the 1,000-pound-per-year factor was felt to be reasonably representative. Emissions from open dumps, backyard burning, and on-site incineration must, therefore, be viewed within these limitations.

Results

An estimated 146,410 tons of refuse was disposed of in 1964 in the study area by all types of burning. Two multiple-chamber incinerators - a municipal incinerator serving the City of Charleston, and an industrial incinerator serving one of the chemical complexes - reportedly consumed 45,000 tons of refuse in 1964. Refuse disposed of in single-chamber incinerators, including "teepees," was estimated at 10,190 tons. The remaining 90,720 tons was disposed of at open dumps or by backyard burning. One sanitary landfill was reported, and the populace served by this landfill was not included in the estimate of per capita refuse generation for backyard burning or open dumps.

Refuse disposal as a whole contributed an estimated 9.8 tons of particulates per day in 1964 to the ambient air. Backyard burning constituted about 51 percent of the particulates emitted from combustion of refuse, with the remaining 49 percent attributed to burning dumps and incineration. Gaseous pollutants contributed from the incomplete combustion of refuse are significant when compared with other, generally more notorious sources. Tables 3-8 and 3-9 summarize by method of refuse disposal the amount of refuse disposed of and the corresponding particulate and gaseous emissions.

Table 3-8. ESTIMATED PARTICULATE EMISSIONS FROM SOLID REFUSE DISPOSAL

Source classes	Material consumed, tons/yr	Particulates		
		tons/day	tons/yr	Percent of total
Refuse disposal				
Burning dump	65,560	4.2	1541	42.7
Backyard burning	24,160	5.0	1812	50.2
Incinerators				
Single chamber	10,190	0.3	127	3.5
Multiple chamber	45,500	0.3	128	3.6
Totals	145,410	9.9	3608	100

Table 3-9. ESTIMATED INORGANIC AND ORGANIC EMISSIONS FROM SOLID REFUSE DISPOSAL (tons/yr)

Source classification	Sulfur oxides	Nitrogen oxides	Carbon monoxide	Ammonia	Hydrocarbons	Aldehydes	Organic acids
Refuse disposal							
Burning dump	39	20	n.a.[a]	75	9,178	131	49
Backyard burning	10	6	n.a.	19	3,382	43	18
Incinerators							
Single chamber	n.a.	8	102	n.a.	102	26	n.a.
Multiple chamber	43	47	15	6	27	22	11
Total	92	81	117	100	12,689	222	78

[a] n.a. - Indicates data not available.

EMISSIONS FROM MISCELLANEOUS SOURCES

Emission sources other than combustion of fuel, industrial processes, and refuse disposal are included in this section. Included are gasoline evaporation from all sources, solvent evaporation, and municipal waste-treatment facilities. Solvent emissions are reported in this section, not in "Emissions from Industrial

Processes," even though a significant percentage of the solvent losses is from industrial sources.

Gasoline Evaporation Losses

Methodology - Information was obtained by personal contact regarding the type of storage tanks used, their average filled capacities, the plant throughput, method of filling the tanks and transportation vehicles, and types of air pollution control equipment for all the gasoline bulk-storage plants located in the study area. This information was used to estimate losses from bulk plants and transportation. Evaporation losses from the filling of both station storage and vehicle tanks and from road vehicles were calculated from the estimated amount of gasoline consumed in the study area. Gasoline evaporation losses from bulk plants, transportation, filling stations, and vehicles were estimated by means of published emission factors (see Appendix C).

Results - The estimated losses from breathing and filling operations at area bulk plants were 1,386 tons of hydrocarbons per year. A reported 65.5 percent of the gasoline is stored in floating-roof tanks; the remaining amount, in cone-roof tanks. One large bulk plant with cone-roof tanks has interconnecting vapor lines, which should reduce tank breathing losses. Submerged filling, or the equivalent, was reported being used by all the area's bulk plants to reduce gasoline emissions during filling operations. None of the plants reported that vapor recovery systems were being utilized.

Splash-filling is normally used at service stations and in filling vehicle tanks. Estimated emissions from these sources were 346 tons of gasoline per year for filling stations storage tanks and 349 tons per year for the filling of vehicle tanks.

The vehicles consuming the gasoline are the largest source of evaporation losses. Fuel losses through gasoline tank breathing, the hot "soak" losses of fuel in the carburetor, and the crankcase breathing devices were estimated to be 2,766 tons of hydrocarbons or gasoline per year. The losses from the crankcase "blowby" are now being controlled on the new model cars, but, at present, no attempts have been made to control these losses from the older vehicles or the evaporation losses from the carburetor or gasoline tank.

The total hydrocarbons or gasoline evaporation losses from all sources as reported in Table 3-10 were estimated to be 4,847 tons per year, or approximately

Table 3-10. ESTIMATED EMISSIONS FROM EVAPORATION OF GASOLINE AND SOLVENTS

	Emissions	
	tons/yr	Percent of total
Gasoline evaporation		
Bulk plants		
Breathing and filling losses	1,386	19.8
Filling stations		
Station tanks	346	4.9
Automobile tanks	349	5.0
Motor vehicles		
Carburetors, crankcase, and gas tanks	2,766	39.6
Total gasoline evaporation	4,847	69.3
Solvent evaporation		
Dry cleaning	2,024	29.0
Industrial	120	1.7
Total solvent evaporation	2,144	30.7
Total evaporation	6,991	100.0

5.4 percent of the overall hydrocarbon emissions from all sources.

Solvent Evaporation Losses

Methodology - Information on solvent losses was obtained from the questionnaires completed by industrial and commercial establishments. All losses reported were estimated to be solvent evaporation to the ambient air.

Results - Solvent evaporation losses were primarily from dry cleaning, industrial paints and coatings, metal cleaning and degreasing, and printing. Listed in Table 3-10 are the total reported solvent evaporation losses for the study area. The principal source of the reported solvent losses - the dry cleaning plants - were responsible for emitting 2,024 tons of solvent per year. The per capita losses are 18 pounds per capita per year, or approximately 4 times the per capita losses reported in the Los Angeles or San Francisco area.[17] This figure seems high, whereas the reported solvent losses from other sources would appear to be low. The overall per capita emission of 19 pounds of solvent per capita per year is comparable to the 21.5 pounds per capita-per year emission in St. Louis.[13]

Municipal Waste Treatment Facilities

Methodology - The major municipal waste treatment facilities in the study area were contacted and inspected by staff members.

Results - The facilities checked had primary treatment of municipal waste and, at one installation, primary treatment of industrial wastes. Treatment plants are potential sources of odor emissions and must be properly operated to prevent conditions that may cause objectionable odors. All the plants visited practiced some type of odor control or odor reduction. These methods of operation varied from the introduction of chlorine into the inlet feed and into liquids flowing to other units in the treatment plant, to the scheduled cleaning of lines and equipment, and to the use of masking agents either introduced into liquids or to the atmosphere. Officials at two of the sewage plants visited recognized that odor problems existed and were using masking agents to try to reduce the effects of these odors.

The waste treatment plants reviewed consisted of pretreatment facilities or screening, comminuting and degritting operations; then primary treatment or sedimentation; followed by sludge or solids handling, which includes pumping, sludge digestion, and sludge thickening; and, last, the disposal of the solid waste and liquid effluent. Though no secondary treatment facilities are presently in operation, several are either under construction or in the planning stage.

SUMMARY

Industrial and utility power plants are the principal sources of particulate, sulfur dioxide, and nitrogen oxide emissions. Transportation is the principal source of carbon monoxide, and industrial processes are the major sources of acid mist, hydrocarbon, aldehyde, and ammonia emissions. Table 3-11 and Figure 3-2 present the commonly reported emissions by source classification, and Figure 3-3, 3-4, 3-5, 3-6, and 3-7 show a breakdown of these individual pollutants by area.

Particulates

The principal source of particulate emissions is the combustion of fuels (82.2 percent), mainly coal, in the utility and industrial boiler plants. Industrial processes account for another 14 percent of the overall particulate emissions. South Charleston (35.9 percent), Alloy (20.8 percent), Cabin Creek-Glasgow (12.4 percent), and Institute-Dunbar (17.2 percent) contribute approximately 86.3 percent of the particulates emitted. Ambient air measurements of particulates can be correlated with particulate emissions in the area near the sampling site, with the exception

Table 3-11. TOTAL ESTIMATED EMISSIONS
(tons/yr)

Source classification	Particulates	Sulfur oxides	Nitrogen oxides	Carbon monoxide	Hydro-carbons^a	Alde-hydes	Organic acids	Ammonia
Utility power plants	15,513	27,320	14,410	360	144	4	n.a.	n.a.
Industrial heat and power	93,623	57,326	34,497	4,772	1,617	63	434	3
Space heating (excluding industrial)	256	224	716	279	56	1	355	2
Transportation	1,108	550	5,123	90,704	17,580	196	339	60
Refuse	3,608	93	81	117	12,689	223	79	101
Process	18,615	24,150	1,240	6,120	49,969	912	294	600
Evaporation (all sources)					6,991			
Total	132,723	109,663	56,067	102,352	89,046	1.397	1,501	766

^{a}Includes all organic compounds except aldehydes and organic acids.

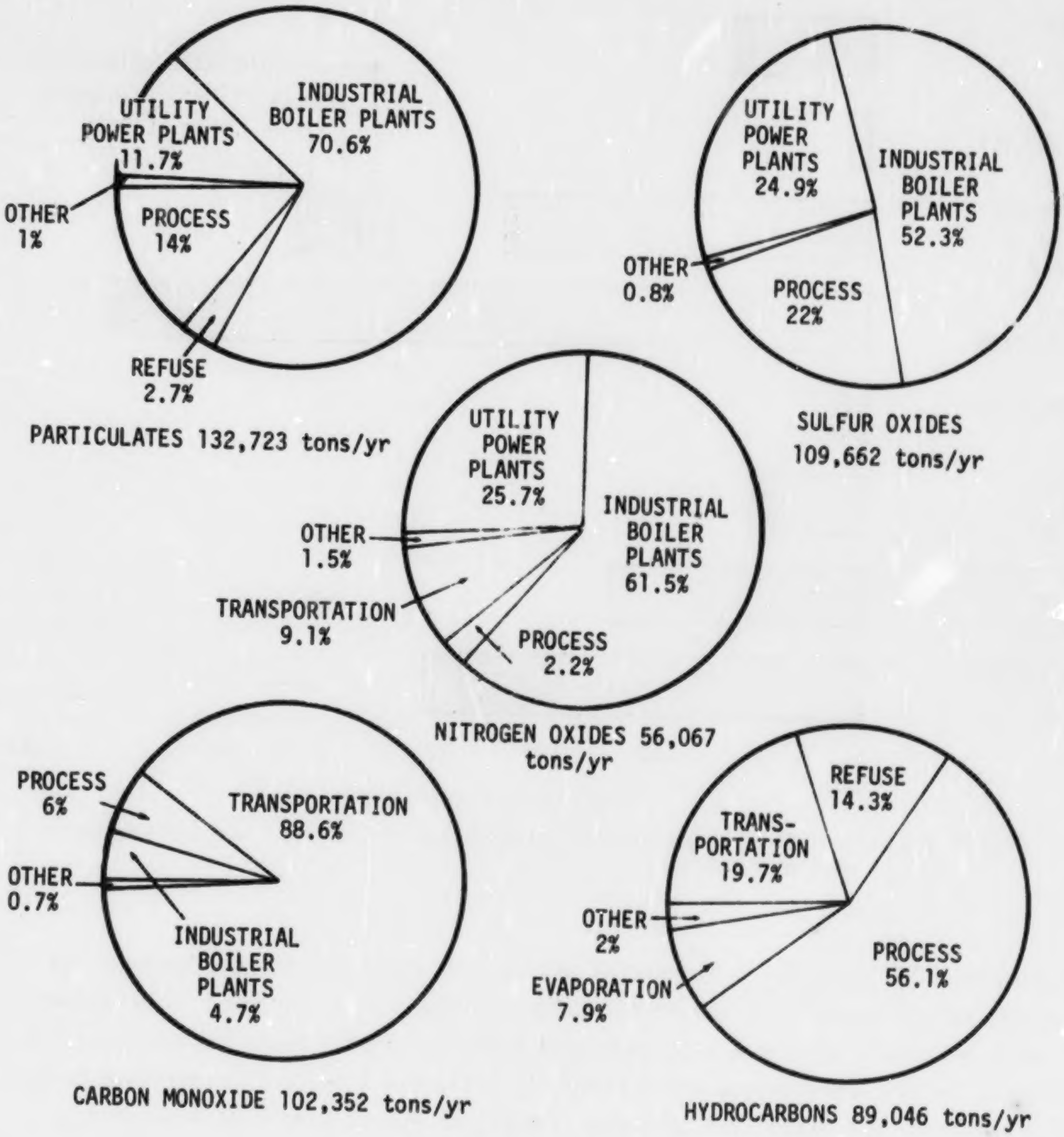

Figure 3-2. Principal source categories of major pollutants in Kanawha Valley.

of the suspended particulate measurements in the Kanawha City area of Charleston. Emissions from one source area are frequently transported into adjacent source areas, which may explain the high particulate levels in Kanawha City.

Sulfur Oxides

The principal source of sulfur oxide emissions (77.2 percent) is the combustion of fuel, primarily coal, for both utility and industrial heat and power. The other

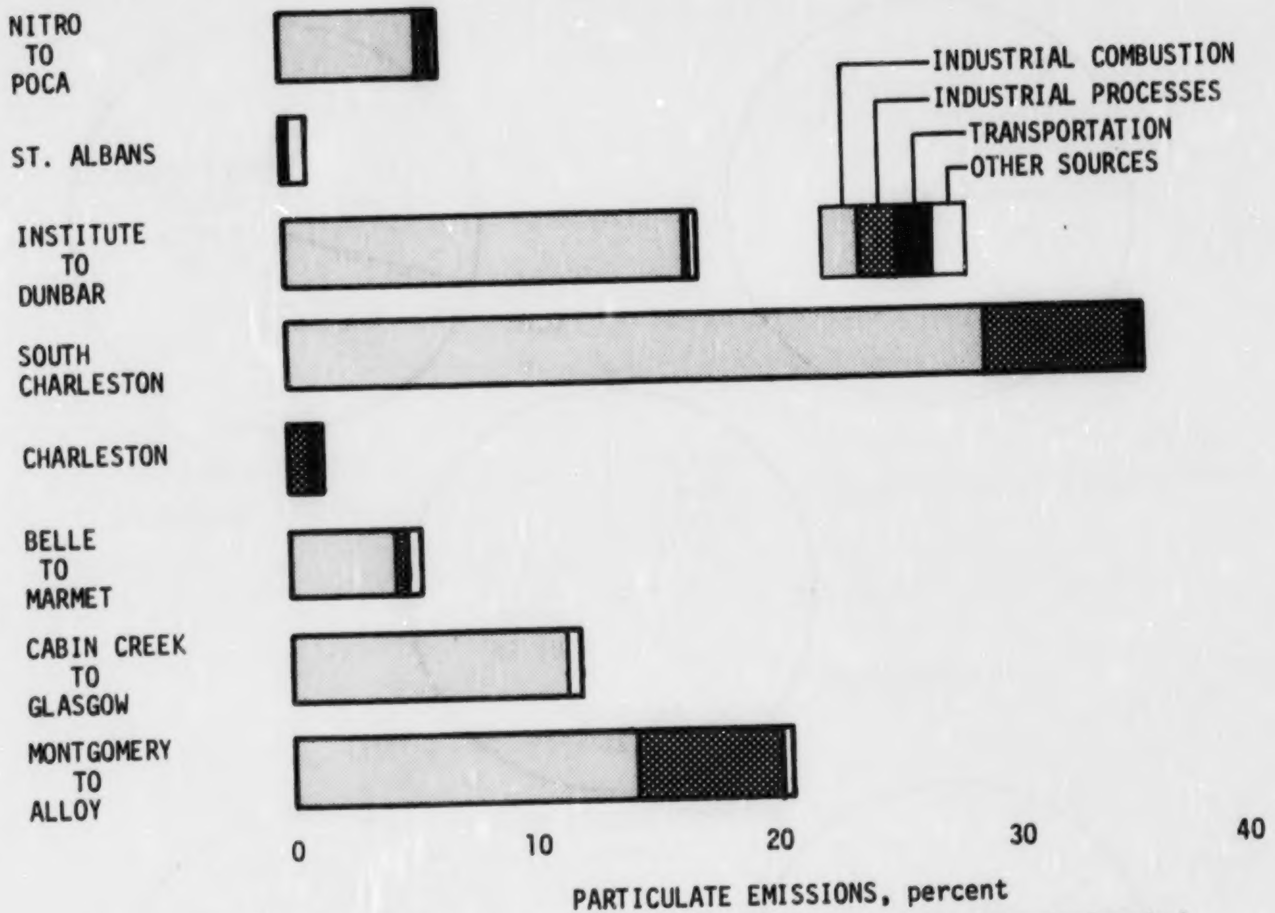

Figure 3-3. Contribution to overall particulate emissions from designated geographic areas.

major source (22 percent) is industrial processes. These two sources contribute approximately 99 percent of the sulfur oxides released to atmosphere. A breakdown of these emissions by source area indicated that five areas, South Charleston (33.6 percent), Cabin Creek-Glasgow (25.4 percent), Belle (14.1 percent), Institute-Dunbar (14.0 percent), and Nitro (9.3 percent), contribute approximately 96.4 percent of the total emissions, with the first four areas contributing 87.1 percent.

Nitrogen Oxides

The combustion of fuel for both utility and industrial heat and power contributes 87.2 percent of nitrogen oxide emissions. Another significant source is transportation (9.1 percent), and other sources contribute the remaining 3.7 percent of these emissions. As expected, the highly industrialized areas of Institute, South Charleston, Cabin Creek-Glasgow, and Belle, with their large power and boiler plants, are the principal source areas of nitrogen oxides.

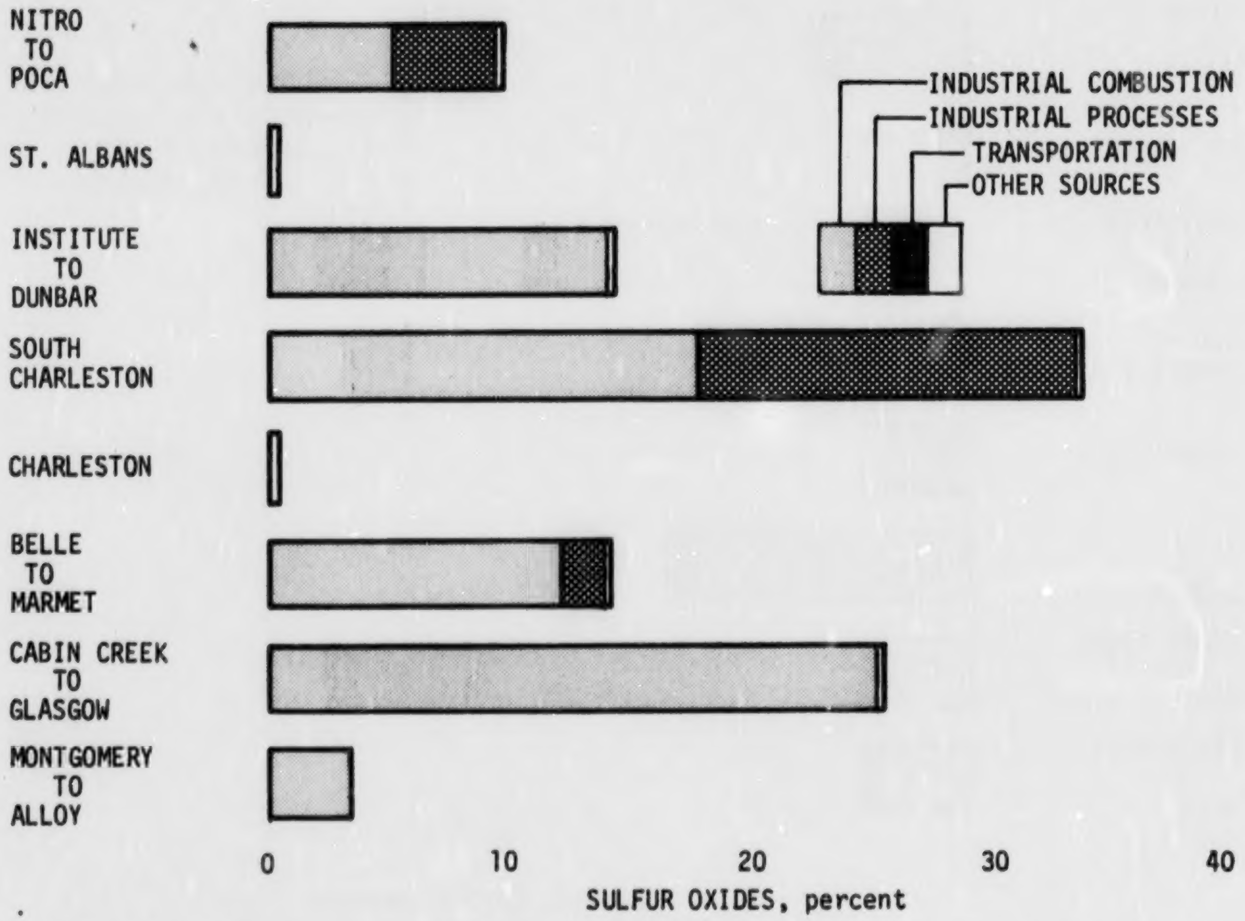

Figure 3-4. Contribution to sulfur oxide emissions from designated geographic areas.

Carbon Monoxide

Transportation is the principal source of this emission (88.6 percent), with gasoline-powered road vehicles contributing the major portion. Industrial process (6.0 percent) and combustion of fuel for industrial heat and power (4.7 percent) also contribute significant amounts. The major source areas in order of magnitude are Charleston, Belle, South Charleston, and St. Albans, which are not necessarily the major industrial areas. The high levels in these areas reaffirm the nonindustrial character of the source of this pollutant. Some of these areas are more indicative of high traffic densities than areas of industrialization.

Hydrocarbons

The principal sources of hydrocarbon emissions are industrial processes (56.1 percent). Other significant sources are transportation (19.7 percent), refuse disposal (14.3 percent), and evaporation losses (7.8 percent). These sources contribute approximately 97.9 percent of the total hydrocarbon emissions. South

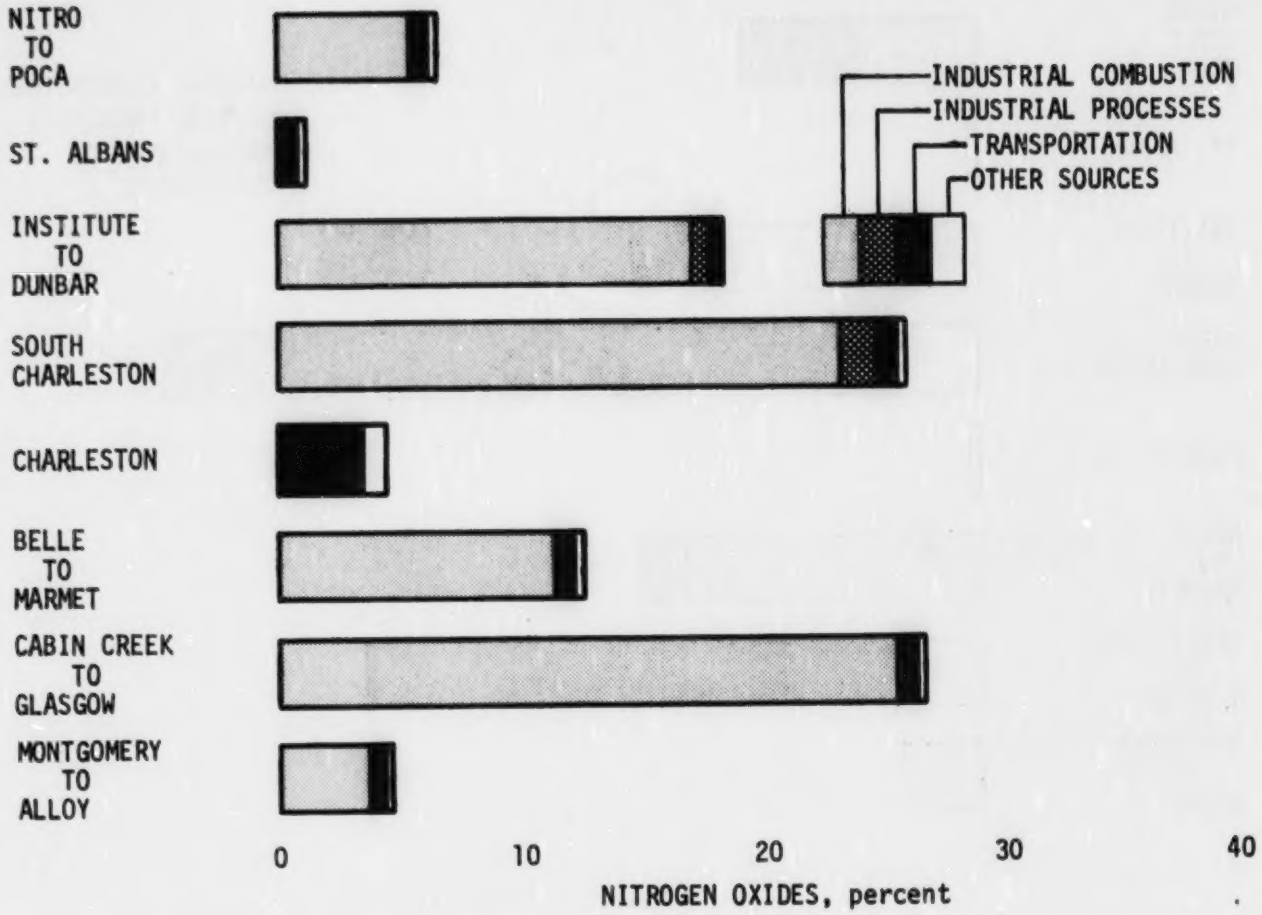

Figure 3-5. Contribution to overall nitrogen oxide emission from designated geographic areas.

Charleston, Nitro, and the Institute industrial areas, where organic chemicals or organic products such as rubber and viscose rayon are produced, are the major source areas of organic compounds. Charleston, though without a large chemical plant, has high traffic densities, many dry cleaning establishments, fabrication plants, several gasoline bulk storage plants, and many gasoline service stations. The emissions of objectionable odors were not inventoried as such. An examination of the sections on chemical processes and waste treatment facilities, however, indicates the presence of potentially odorous materials.

The seasonal variation of emissions was not thought to be significant. The estimated emissions of carbon monoxide and hydrocarbons were highest in the summer season because of the greater consumption of gasoline for transportation and the increase in evaporation losses due to higher ambient temperatures. The emissions of particulates and sulfur oxides were slightly higher during the winter season because of the increased use of fuel for space heating and for industrial heat and power. The increase in nitrogen oxide emissions from transportation during the

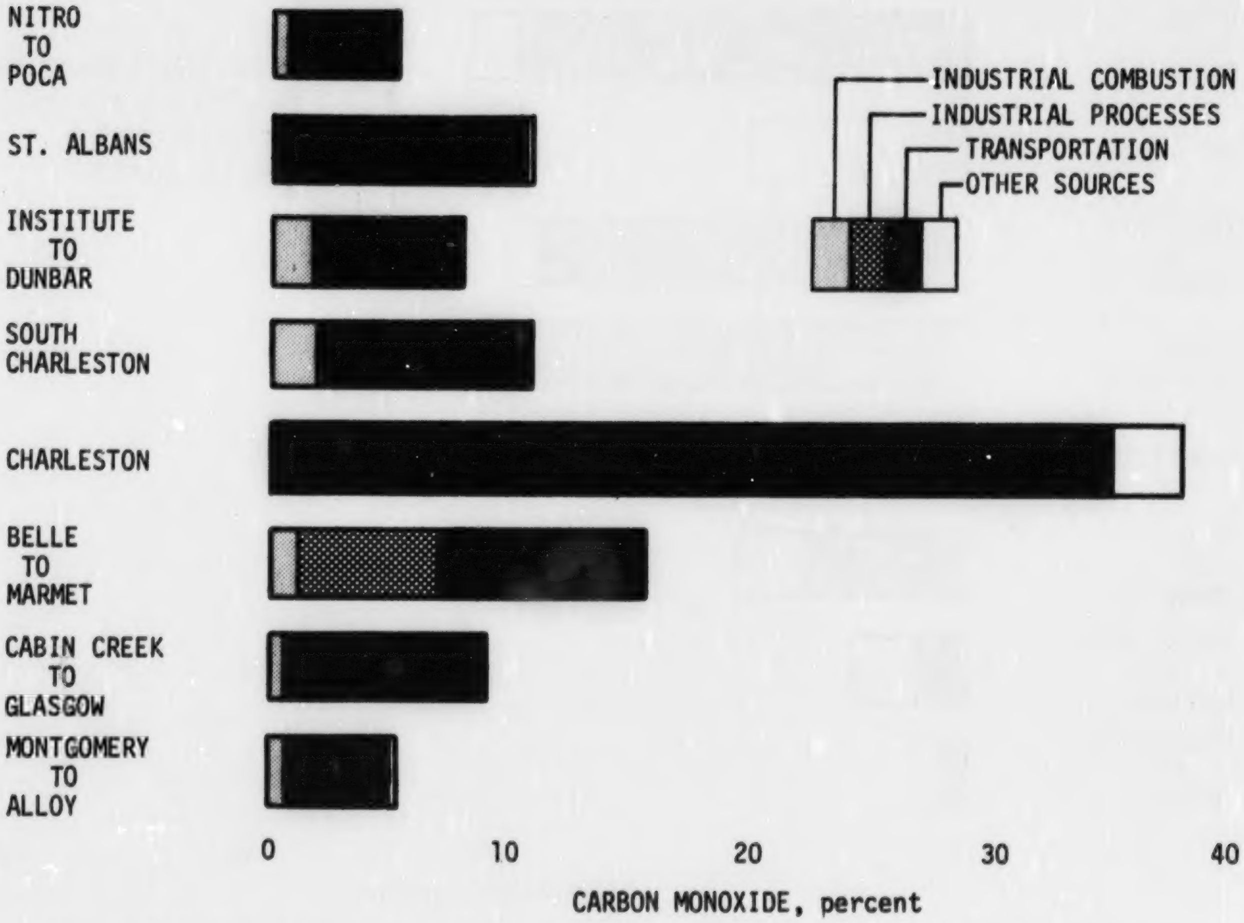

Figure 3-6. Contribution to overall carbon monoxide emissions from designated geographic areas.

summer is offset in the winter by an increase in these emissions from the combustion of fuels for heat and power. Particulate emissions from industrial processes were considered to be relatively constant except for some smaller source industries such as asphalt mix and concrete batch plants. Seasonal variation in emissions from the disposal of refuse was also considered to be negligible. Seasonal variation of fuel consumption is shown in Table 3-3A. The effect of seasonal variations on emissions from the combustion of gasoline in road vehicles is presented in Table 3-3B.

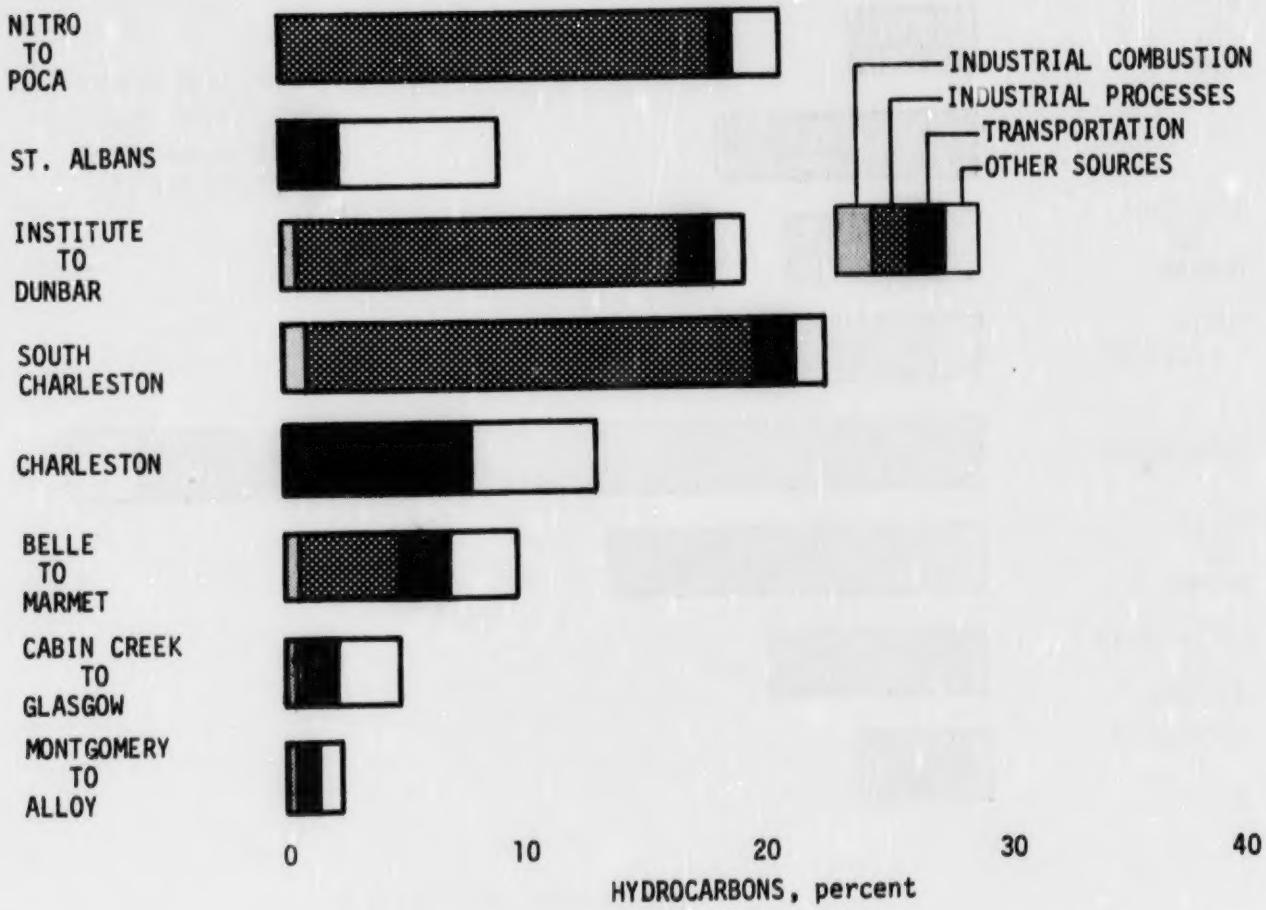

Figure 3-7. Contribution to overall hydrocarbon emissions from designated geographic areas.

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SECTION IV.
AIR QUALITY MEASUREMENTS

INTRODUCTION

An air monitoring network was established in the Kanawha Valley study area to evaluate the air pollution problem and to provide information necessary for the development of an air resource management program. This network was designed to measure both the extent and intensity of the air pollution problem in the Kanawha River Valley extending from Gauley Bridge to the City of Nitro.

The network included fixed sampling stations, a mobile laboratory, and various other sites used intermittently for special sampling. There were 27 fixed stations, 7 mobile laboratory sites used on a seasonal basis, 9 materials deterioration panels located at hygrothermograph stations, and 11 additional sites for special studies. Several of the sampling stations were established prior to the initiation of the study by the staff of the West Virginia Air Pollution Control Commission. The additional stations were established to supplement those operated by the Commission in order to obtain a more comprehensive picture of air pollution problems within the valley.

Air contaminants measured at these sampling sites included settleable, suspended, and soiling particulates, as well as specific pollutant gases, such as sulfur dioxide, nitrogen dioxide, and carbon monoxide. Also measured was a group of pollutant gases known as "oxidants." Attempts were made to measure the concentration of hydrocarbons, but due to instrument difficulties, the data were not considered valid.

FIXED SAMPLING STATIONS

The concentration of suspended and settleable particulate matter was measured at these stations using a high-volume air sampler and a dustfall jar, respectively. The soiling particulate matter was measured by means of an AISI (American Iron and Steel Institute) tape sampler[1] and the sulfation rate was evaluated using a lead peroxide candle. The deterioration of materials was determined by exposing metals and both synthetic and natural textile fibers to the ambient air. Figure 4-1 is a photograph of a typical sampling station.

The locations of the various sampling stations were carefully chosen to insure that a representative air sample at the particular area would be obtained. Consideration was given to such factors as: (1) adequate coverage of entire study area, (2) proximity to commercial, industrial, or residential areas, (3) sample not unduly affected by sources in immediate vicinity of sampling site, (4) representative of area of interest, (5) availability of power (where needed) and (6) ease of access of equipment. Figure 4-2 is a map indicating the location of the sampling sites in the study area. Also, a list of the stations with the address, description of site and area, and equipment is presented in Appendix E.

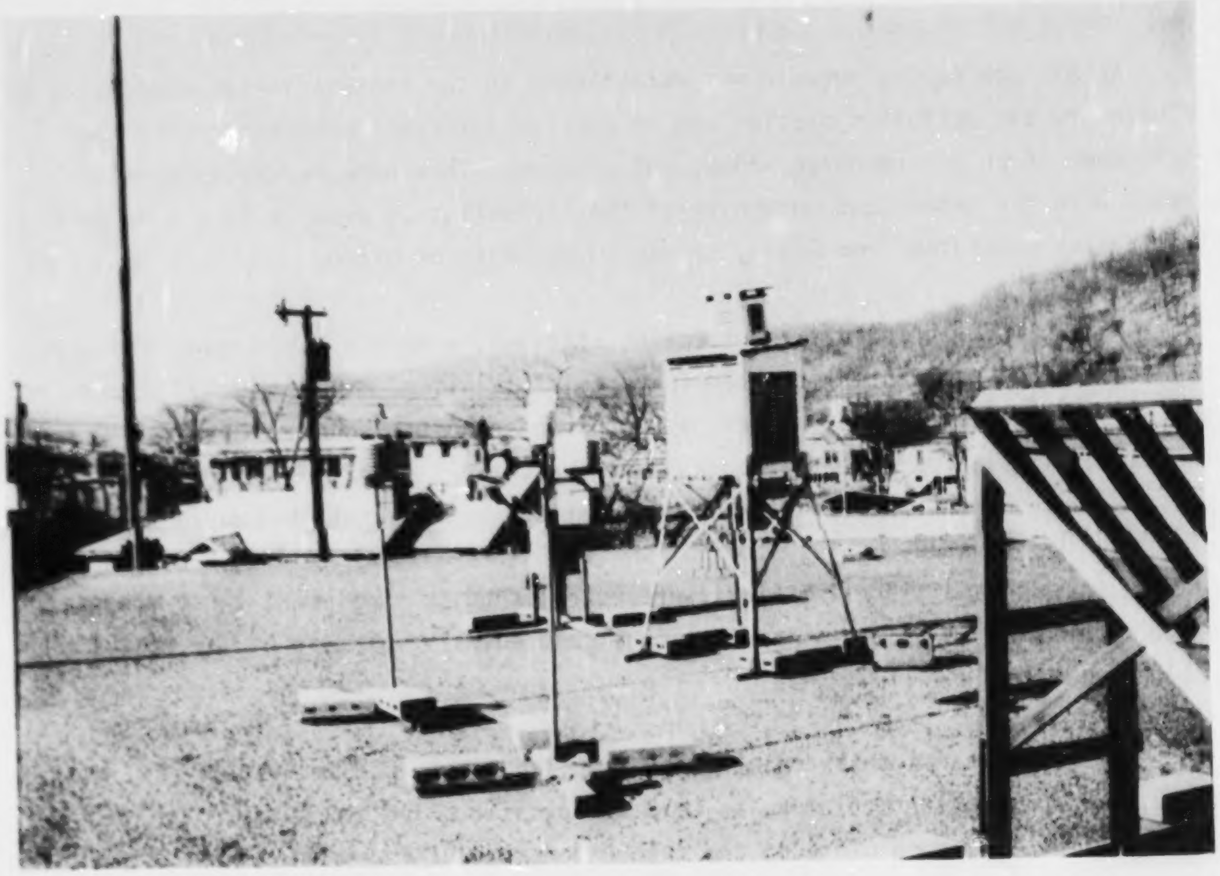


Figure 4-1. Photograph of sampling equipment located at North Charleston Fire Station. (North Charleston West).

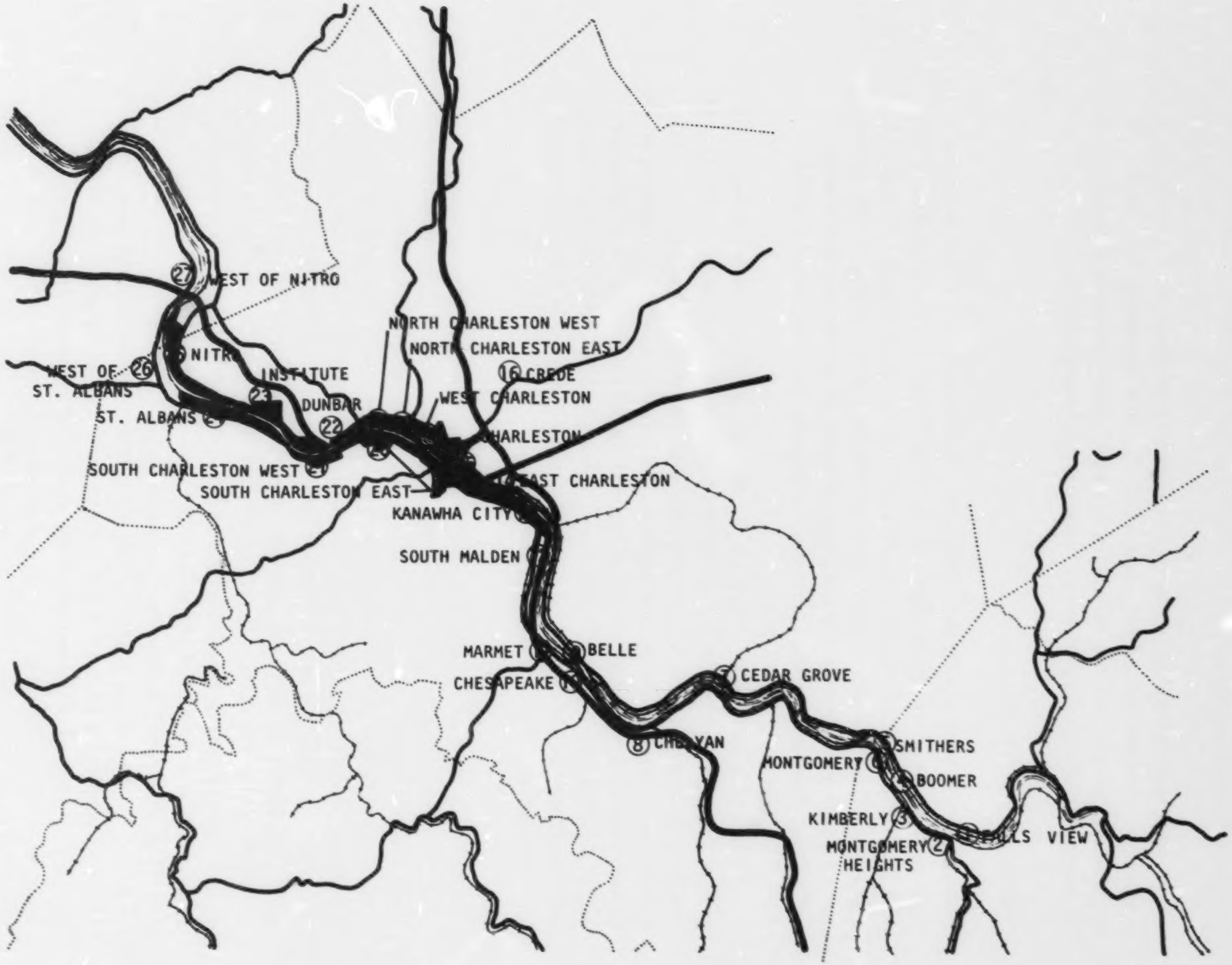

27 WEST OF NITRO
26 WEST OF ST. ALBANS
NITRO
23 INSTITUTE
ST. ALBANS
DUNBAR
22
SOUTH CHARLESTON WEST
SOUTH CHARLESTON EAST
NORTH CHARLESTON WEST
NORTH CHARLESTON EAST
16 CREDE
WEST CHARLESTON
CHARLESTON
EAST CHARLESTON
KANAWHA CITY
SOUTH MALDEN
MARMET
BELLE
CHESAPEAKE
7 CEDAR GROVE
8 CHELYAN
SMITHERS
6 MONTGOMERY
4 BOOMER
3 KIMBERLY
2 MONTGOMERY HEIGHTS
FALLS VIEW

Figure 4-2. Location of fixed sampling stations in Kanawha Valley.

Suspended Particulate Matter

Suspended particulate matter was measured at 14 fixed sampling sites with high-volume air samplers and AISI tape samplers. The sources of this particular air contaminant are from the combustion of fossil fuels and waste materials as well as industrial, chemical, and physical processing of materials.[2]

High-volume Air Sampler

High-volume Air Sampler - Method - High-volume air samplers use a vacuum cleaner type of blower to draw air through a glass fiber filter.[3] The suspended particulate matter is collected on the preweighed filter for approximately 24 hours at an average air flow of about 50 cubic feet per minute. After exposure, the filter is again weighed and the amount of particulate matter is determined by the weight difference. The results are reported as micrograms per cubic meter ($\mu g/m^3$).

Composite samples were analyzed for various metals, sulfates, ammonia, and benzene soluble organic material by the U. S. Public Health Service, Laboratory of Engineering Science. Selected samples were also analyzed microscopically. The samplers were operated during the work week on a random schedule (approximating the National Air Sampling Network's schedule), with two 24-hour samples on consecutive days. Selected stations were operated on Saturday and Sunday to try to determine whether ambient air concentrations were affected by changes in industrial operations and other weekend activities.

Results - A summary of suspended particulate measurements for the Kanawha Valley Study Area for the period of January 1964 through December 1965 is presented in Table 4-1. Data collected prior to this study by the West Virginia Air Pollution Control Commission are also included in the reported results. Listed in the table are the arithmetic and geometric means, maximum and minimum values, and the maximum quarterly geometric mean for each sampling station. During this sampling period the geometric means of suspended particulate measurements ranged from 110 at the west of Nitro station to 332 $\mu g/m^3$ at Montgomery. The results reported for all the sampling stations exceeded the goal of 100 $\mu g/m^3$ (annual geometric mean) suggested by the Joint Study Technical Committee and approved by the West Virginia Air Pollution Control Commission.[4] Geometric means of 290 and 253 $\mu g/m^3$ were measured at the Smithers and South Charleston stations. These stations were considered to be representative of their areas and had, with the exclusion of the Montgomery station, the highest measurements in the study area. The Montgomery station was found to be unduly affected by a nearby emission source and was not considered representative of that particular area of the valley. Both the Smithers and South Charleston stations are surrounded by residential, commercial, and heavy industrial areas.

Table 4-1. KANAWHA VALLEY SUSPENDED PARTICULATE DATA
JANUARY 1964 TO DECEMBER 1965
($\mu g/m^3$)

Station location	Station number	Arithmetic mean	Geometric mean	Maximum value	Minimum value	Maximum quarterly geometric mean
Falls View	1	179	141	703	23	175
Smithers	5	347	290	724	58	323
Montgomery	6	413	332	1,178	57	402
Cedar Grove	7	235	186	1,044	25	240
Marmet	11	242	187	958	31	225
Kanawha City	13	287	227	1,081	58	245
Charleston	15	189	160	722	51	183
West Charleston	17	209	181	603	47	232
North Charleston, W.	19	241	204	750	41	333
South Charleston, E.	20	298	253	899	73	394
Dunbar	22	199	159	850	12	216
St. Albans	24	223	166	1,062	34	235
Nitro	25	179	141	964	38	207
West of Nitro	27	132	110	466	27	158

Figure 4-3 is a comparison of results from the Kanawha Valley with National Air Sampling Network results from 1957 to 1961 by population of urban sampling sites.[3] The concentrations measured at 8 of the 14 sampling stations in the study area are above the average for urban areas with 3 million or more people, such as New York City and Los Angeles.[5] Measured concentrations from all the stations are above the average (1957-60) reported for urban areas above 100,000 to 400,000 population, and all are greater than the national urban average (1957-63).[3]

Seasonal variations of suspended particulate concentrations are reported in Table 4-2. The highest quarterly concentrations occurred during the fall of 1964, with the exception of the three stations in the Alloy area. The maximum concentrations for Montgomery and Smithers occurred during the winter and for Falls View in the spring. Seasonal variation of suspended particulate results at the Smithers station probably represents the effects of seasonal meteorological changes because the emissions around that station were reported to be relatively constant. This conclusion is shown by the small difference of 39 $\mu g/m^3$ between the maximum and minimum quarterly geometric means. The seasonal variation at the South Charleston East station (fall of 1964 vs summer of 1965) was 196 $\mu g/m^3$. The variation of the 1965 means was 35 $\mu g/m^3$. This large variation in seasonal means between the years

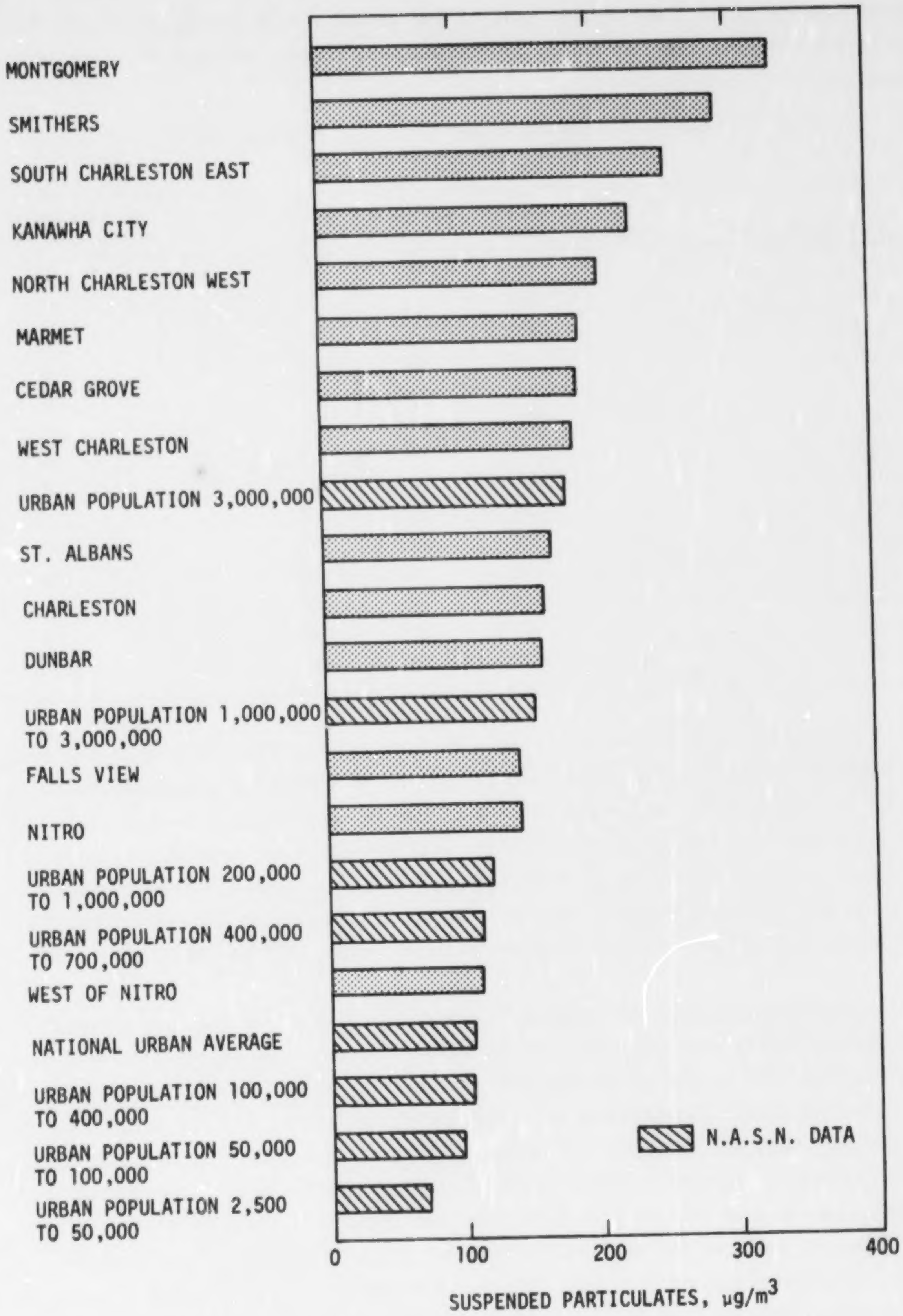


Figure 4-3. Comparison of Kanawha Valley study with National Air Sampling Network suspended particulate results.

Table 4-2. KANAWHA VALLEY SUSPENDED PARTICULATE DATA[1]
($\mu g/m^3$)

		Quarterly geometric mean					
		1964	1965				
Station location	Station number	Fall	Winter	Spring	Summer	Fall	All data
Falls View	1	162	141	175[a]	151	97	141
Smithers	5	304	323	284	285	301	290
Montgomery	6	369	402	391	256	271	332
Cedar Grove	7	240	176	181	169	179	186
Marmet	11	225	193	199	125	165	187
Kanawha City	13	245	234	240	153	-[b]	227
Charleston	15	183	213	161	143	178	160
West Charleston	17	232	226	186	124	188	181
North Charleston, W.	19	333	277	216	170	133	204
South Charleston, E.	20	394	220	227	198	233	253
Dunbar	22	216	135	128	121	145	159
St. Albans	24	235	139	148	97	191	166
Nitro	25	207	121	132	92	112	141
West of Nitro	27	158	107	113	98	112	110

[a] Underlined values are maximum quarterly concentrations.

[b] Insufficient data.

1964 and 1965 might be explained on the basis of the occurrence of nearby forest fires and a stagnant air mass which covered the entire area.

A comparison of 1964 suspended particulate data obtained from the study sampling network and an independent industrial sampling network is presented in Table 4-3. An examination of these data indicates relatively close agreement for the same three sampling stations.

The suspended particulate sample results were compared with the goal of 100 $\mu g/m^3$ adopted by the West Virginia Air Pollution Control Commission for the Kanawha Valley and with adopted or proposed ambient air quality standards or criteria of other areas in the United States. A compilation of these goals or standards is presented in Table 4-4. Figure 4-4 is a comparison of study data with the proposed goal for the Kanawha Valley and with the standards and goals of other areas. This comparison indicates that all the study area stations exceeded the goal proposed by the Commission and also exceeded the standards or goals of the other areas listed in Table 4-4.

Table 4-3. 1964 KANAWHA VALLEY SUSPENDED PARTICULATE DATA COMBINED INDUSTRIAL AND STUDY SAMPLING NETWORKS ($\mu g/m^3$)

Station location	Station number	Arithmetic mean	
		Industrial network[a]	Study network[b]
Gauley Bridge		149	
Falls View	1		177
Smithers	5		374
Montgomery	6		485
London Locks		494	
Cedar Grove	7		276
Marmet	11		292
Kanawha City	13		362
Kanawha City		377	
Charleston	15		166
Charleston		223	
West Charleston	17		229
North Charleston			355
South Charleston			374
Dunbar	22		255
St. Albans	24		296
St. Albans		257	
Nitro	25		236
West of Nitro	27		158
Winfield Locks		152	
Blue Creek		46	
Cliffside		107	

[a] Based on 26 samples per year, NASN schedule.

[b] Based on 2 samples per week, approximately the NASN schedule.

The chemical analyses of quarterly composite samples of high-volume filters are presented in Tables 4-5, -6, -7, -8, and -9. Individual station composites of samples from Smithers, Cedar Grove, Kanawha City, South Charleston, St. Albans, and Nitro were analyzed for the fall of 1964, spring and summer of 1965, and are indicated in Tables 4-5, -6, and -7, respectively. Composite samples for all stations were analyzed for the winter (1964-1965) season and are shown in Table 4-8. The seasonal averages, including the maximum and minimum, of the results of chemical analysis are reported in Table 4-9. Also included are the arithmetic mean and maximum values as analyzed and reported in the National Air Sampling Network (NASN)

Table 4-4. SUSPENDED PARTICULATE AMBIENT AIR QUALITY STANDARDS, OBJECTIVES AND GOALS IN THE UNITED STATES, 1966

Colorado[6] - 120 $\mu g/m^3$, average for any 3-month period

New York State[7] - Objective varies according to regions and subregions

Regional Objective C

Subregion 3 - 80 $\mu g/m^3$, <50 percent of values
120 $\mu g/m^3$, <84 percent of values

Subregion 4 - 100 $\mu g/m^3$, <50 percent of values
150 $\mu g/m^3$, <84 percent of values

Regional Objective D

Subregion 3 - 100 $\mu g/m^3$, <50 percent of values
150 $\mu g/m^3$, <84 percent of values

Subregion 4 - 135 $\mu g/m^3$, <50 percent of values
200 $\mu g/m^3$, <84 percent of values

Oregon[8] - Concentration shall not exceed the stated value plus normal background

Residential and Commercial Areas - 150 $\mu g/m^3$, plus normal background value

Heavy Industrial Area - 250 $\mu g/m^3$, plus normal background value

Pennsylvania[9]
150 $\mu g/m^3$, maximum allowable outside property, calculated using diffusion equations

St. Louis[10] (Metropolitan Area) - Maximum Permissible
75 $\mu g/m^3$, annual geometric mean
200 $\mu g/m^3$, not to be exceeded 1 percent of days per year

West Virginia (Goal for Kanawha Valley)
100 $\mu g/m^3$, annual geometric mean
250 $\mu g/m^3$, not to be exceeded 1 percent of days per year

results for the period 1964-1965.[11] The values reported for the study area are for composite, not individual, samples. All the quarterly averages for sulfates, arsenic, and manganese exceeded the 1964-1965 NASN's arithmetic means for the nation's urban system. The NASN, however, usually avoids industrial neighborhoods in larger cities. The maximum quarterly composite sample for manganese obtained during the 1964 fall and 1965 winter quarters actually exceeded the maximum value for a single sample reported by the NASN. For at least half the quarters, the arithmetic means for ammonia, beryllium, zinc, cadmium, titanium, chromium, and

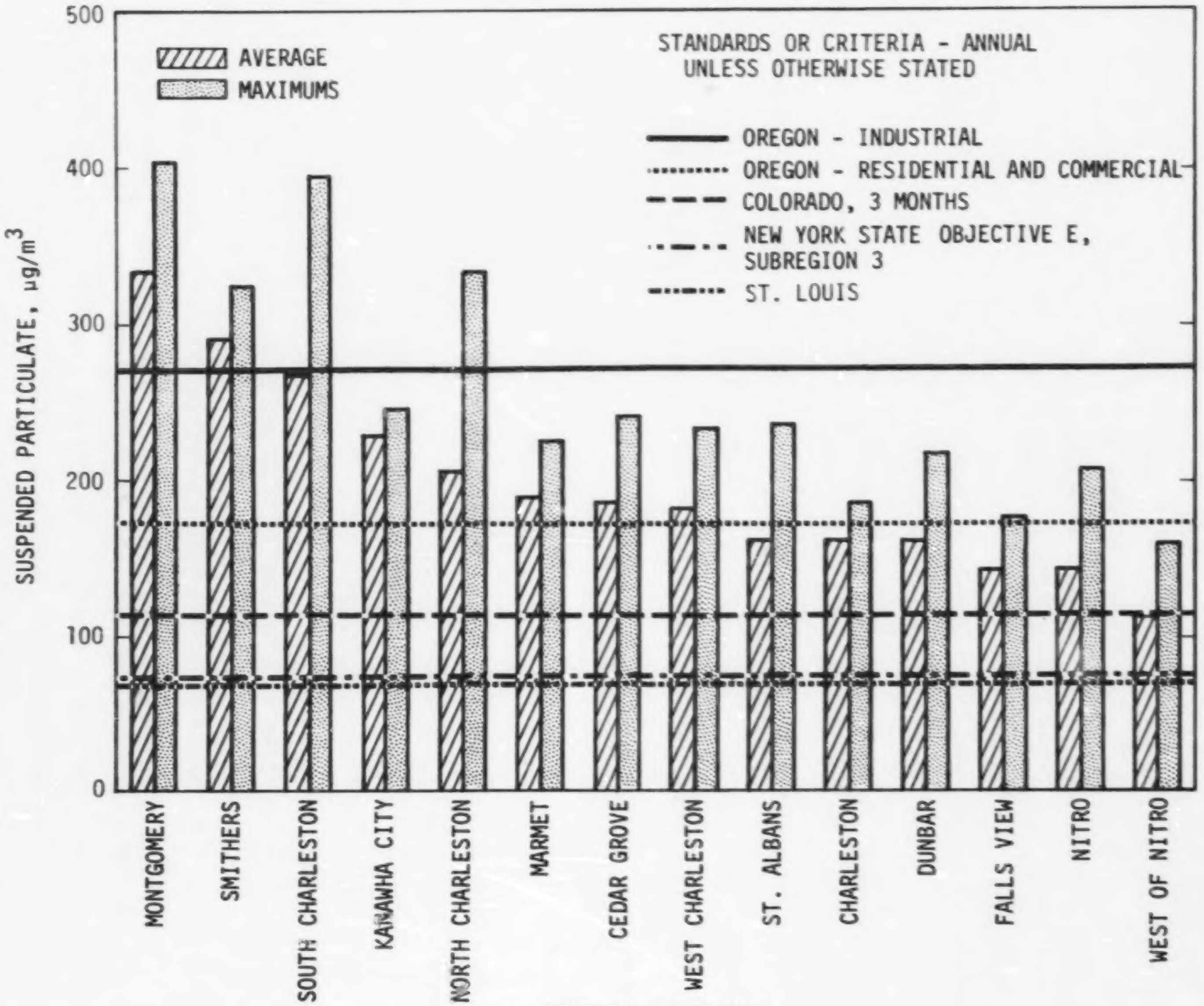


Figure 4-4. Comparison of Kanawha Valley suspended particulate results and air quality standards or criteria.

Table 4-5. CHEMICAL ANALYSES OF QUARTERLY COMPOSITE SAMPLES OF HIGH-VOLUME FILTERS, FALL 1964
($\mu g/m^3$)

	Station (Number)					
Chemical	Smithers (5)	Cedar Grove (7)	Kanawha City (13)	South Charleston	St. Albans (24)	Nitro (25)
Organics[a]	5.4	8.9	12.3	17.8	12.2	9.9
Sulfates[b]	17.5	17.3	31.0	30.5	22.5	23.6
Ammonia[c]	0.3	0.7	5.4	4.5	3.0	2.9
Arsenic	0.13	0.08	0.10	0.18	0.11	0.07
Beryllium	0.000	0.001	0.0028	0.0017	0.001	0.002
Manganese	11.0	4.2	3.3	2.0	0.43	0.59
Lead	0.4	0.5	2.1	2.7	1.3	1.0
Tin	0.01	0.0	0.01	0.01	0.0	0.0
Iron	1.2	2.0	4.3	3.6	1.7	3.1
Copper	0.04	0.05	0.15	0.09	0.03	0.05
Titanium	0.04	0.10	0.18	0.12	0.07	0.11
Vanadium	0.0	0.004	0.017	0.011	0.004	0.01
Zinc	0.64	1.70	1.20	0.90	0.52	0.93
Chromium	0.19	0.11	0.078	0.048	0.016	0.027
Nickel	0.018	0.015	0.041	0.046	0.029	0.042
Molybdenum	0.0	0.0	0.01	0.0	0.0	0.0
Cobalt	0.0	0.0	0.017	0.010	0.006	0.10
Bismuth	0.003	0.002	0.002	0.002	0.0	0.0
Cadmium	0.0	0.0	0.097	0.0	0.0	0.063
Antimony	0.056	0.0	0.0	0.0	0.0	0.0

[a] Benzene soluble organic matter.

[b] Water soluble sulfates.

[c] Water soluble ammonium salts, reported as ammonia.

antimony exceeded the arithmetic means reported by the NASN for the urban areas 1964-1965. Compounds containing beryllium,[12] lead,[13] sulfates,[14,15] and polycyclic compounds[16] are considered toxic at certain concentrations or levels. The toxicity and/or destructive effects on either humans, animals, vegetation, or materials are not definitely known at relatively low concentrations under conditions of long-term exposure.

The suspended particulate measurements made during the 1950-1951 Kanawha Valley Study[17] were compared with the present study results. Table 4-10 presents a

Table 4-6. CHEMICAL ANALYSES OF QUARTERLY COMPOSITE SAMPLES OF HIGH-VOLUME FILTERS, SPRING 1965
($\mu g/m^3$)

Chemical	Station (Number)					
	Smithers (5)	Cedar Grove (7)	Kanawha City (13)	South Charleston	St. Albans (24)	Nitro (25)
Organics[a]	2.7	3.4	3.9	5.0	3.1	3.0
Sulfates[b]	26.7	19.4	20.1	17.8	12.3	12.8
Ammonia[c]	0.4	0.3	2.0	1.4	0.8	0.5
Arsenic	0.18	0.11	0.06	0.07	0.02	0.01
Beryllium	0	0	0.0008	0.0007	0	0
Manganese	4.5	1.8	0.53	0.23	0.06	0.10
Lead	0.3	0.2	0.6	0.6	0.3	0.2
Tin	0	0	0	0	0	0
Iron	1.2	1.1	1.7	1.7	0.8	1.2
Copper	0.03	0.02	0.07	0.05	0.02	0.04
Titanium	0.02	0.04	0.05	0.07	0.01	0.03
Vanadium	0	0	0.005	0.004	0	0.003
Zinc	0.68	0.5	0.42	0.25	0.24	0.35
Chromium	0.160	0.033	0.020	0.015	0.005	0.008
Nickel	0.014	0.011	0.022	0.021	1.007	0.013
Molybdenum	0	0	0	0	0	0
Cobalt	0	0	0	0	0	0
Bismuth	0	0.003	0.002	0.002	0.002	0
Cadmium	0	0	0	0	0	0
Antimony	0	0	0	0	0	0

[a] Benzene soluble organic matter.

[b] Water soluble sulfates.

[c] Water soluble ammonium salts, reported as ammonia.

comparision of the arithmetic averages, maximums, minimums, and the manganese and lead concentrations. A review of the data indicates that there is a decrease in the concentration of manganese at the stations downriver from Marmet and Belle, with a slight increase in concentrations at the Nitro and St. Albans stations. High-volume air samples were not collected upriver or east of the Belle-Marmet area during the 1950-57 study. The analyses of the composite samples of all stations during the winter quarters of 1964-65 indicate that the measured manganese concentrations decrease going downriver from Smithers to the St. Albans-Nitro area. The reported concentrations for all stations east of St. Albans exceeded the NASN national averages. The emission inventory (Section III) indicates that the major

Table 4-7. CHEMICAL ANALYSES OF QUARTERLY COMPOSITE SAMPLES OF HIGH-VOLUME FILTERS, SUMMER 1965 ($\mu g/m^3$)

Chemical	Station (Number)					
	Smithers (5)	Cedar Grove (7)	Kanawha City (13)	South Charleston	St. Albans (24)	Nitro (25)
Organics[a]	3.0	3.7	5.4	5.8	1.8	2.7
Sulfates[b]	22.2	21.9	29.4	30.1	19.7	18.8
Ammonia[c]	0.5	0.6	5.3	4.9	2.6	2.5
Arsenic	0.12	0.06	0.07	0.08	0.02	0.02
Beryllium	0.0	0.001	0.0006	0.0009	0.0	0.001
Manganese	3.00	0.320	0.27	0.17	0.06	0.09
Lead	0.0	0.4	0.5	1.0	0.4	0.3
Tin	0.0	0.0	0.0	0.0	0.0	0.0
Iron	0.5	1.9	1.6	1.4	1.0	1.4
Copper	0.02	0.05	0.08	0.04	0.02	0.03
Titanium	0.01	0.14	0.08	0.07	0.01	0.05
Vanadium	0.0	0.007	0.009	0.005	0.0	0.005
Zinc	0.86	0.98	0.42	0.45	0.38	0.41
Chromium	0.086	0.068	0.012	0.020	0.008	0.011
Nickel	0.0	0.028	0.016	0.026	0.015	0.022
Molybdenum	0.0	0.0	0.0	0.0	0.0	0.0
Cobalt	0.0	0.0	0.0	[illegible]	[illegible]	[illegible]
Bismuth	0.002	0.002	0.001	0.0	0.001	0.0
Cadmium	0.0	0.0	0.0	0.0	0.027	0.009
Antimony	0.0	0.0	0.0	0.0	0.0	0.0

[a] Benzene soluble organic matter.

[b] Water soluble sulfates.

[c] Water soluble ammonium salts reported as ammonia.

source of manganese emissions is in the Alloy area. A review of coal ash analyses[18] precludes the emissions of fly ash from boiler plant stacks as a major source of manganese. The only West Virginia coal reported to have significant manganese concentrations in its ash was located in the northern section of the State and is not burned in the Kanawha Valley.[18] These results reinforce the hypothesis presented by the meteorologist (Section II) that the valley usually acts as one air basin from early evening to late morning due to temperature inversions and down-valley air flows of as high as 5 miles per hour for periods of 10 hours or longer. Emissions from the Alloy area can often be entrapped within the valley walls and carried by down-valley air drift (4 to 5 miles per hour) from the evening through early morning

Table 6-8. CHEMICAL ANALYSES OF QUARTERLY COMPOSITE SAMPLES OF HIGH-VOLUME FILTERS, WINTER 1964-1965
($\mu g/m^3$)

Chemical	Falls View (1)	Smithers (5)	Mont-gomery (6)	Cedar Grove (7)	Marmet (11)	Kanawha City (13)	Charles-ton (15)	West Charles-ton (17)	North Charles-ton, W. (19)	South Charles-ton, E. (20)	Dunbar (22)	St. Albans (24)	Nitro (25)	West of Nitro (27)
Organics[a]	4.3	4.2	7.7	4.7	9.1	10.5	6.6	6.8	5.1	7.8	4.6	6.0	5.2	5.9
Sulfates[b]	13.1	22.9	23.6	19.8	17.8	39.8	22.8	32.8	22.7	22.1	19.4	18.9	16.4	15.7
Ammonia[c]	0.2	0.6	0.5	0.7	1.0	5.5	3.0	4.6	2.9	2.8	2.5	2.1	1.1	1.1
Arsenic	0.04	0.08	0.10	0.05	0.05	0.22	0.14	0.19	0.11	0.08	0.06	0.06	0.03	0.02
Beryllium	0.0	0.0	0.0	0.0	0.001	0.0	0.001	0.0	0.0	0.0	0.0	0.0	0.001	0.0
Manganese	3.40	6.50	13.0	3.50	3.60	1.1	0.91	0.96	0.52	0.26	0.24	0.44	0.28	0.08
Lead	0.2	0.3	0.6	0.4	0.5	0.8	0.9	0.7	0.7	0.6	0.4	0.9	1.4	0.1
Tin	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Iron	1.8	0.3	1.8	1.6	0.6	1.5	0.3	1.6	1.7	0.7	0.8	1.6	2.7	0.8
Copper	0.08	0.04	0.05	0.03	0.09	0.07	0.08	0.06	0.05	0.02	0.04	0.04	0.04	0.02
Titanium	0.05	0.05	0.06	0.05	0.07	0.04	0.10	0.06	0.06	0.03	0.03	0.05	0.06	0.03
Vanadium	0.009	0.0	0.0	0.0	0.007	0.006	0.008	0.008	0.005	0.0	0.004	0.005	0.007	0.008
Zinc	0.80	1.20	1.30	1.10	0.91	0.53	0.61	0.56	0.48	0.28	0.31	0.49	0.43	0.25
Chromium	0.250	0.240	0.21	0.063	0.085	0.032	0.034	0.023	0.012	0.006	0.007	0.019	0.019	0.008
Nickel	0.027	0.020	0.025	0.020	0.049	0.025	0.023	0.015	0.021	0.010	0.011	0.031	0.044	0.026
Molybdenum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cobalt	0.0	0.0	0.0	0.0	0.0	0.0	0.007	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bismuth	0.0	0.003	0.001	0.002	0.0	0.002	0.002	0.002	0.003	0.001	0.0	0.002	0.0	0.002
Cadmium	0.0	0.0	0.014	0.0	0.014	0.025	0.038	0.0	0.0	0.0	0.010	0.049	0.012	0.0
Antimony	0.0	0.057	0.053	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a] Benzene soluble organic matter.

[b] Water soluble sulfates.

[c] Water soluble ammonium salts, reported as ammonia.

Table 4-9. KANAWHA VALLEY QUARTERLY AND 1964-1965 NASN RESULTS OF CHEMICAL ANALYSES OF HIGH-VOLUME FILTER ($\mu g/m^3$)

	Sampling period	Number of station composites analyzed	Benzene soluble fraction	Sulfates	Ammonia	Arsenic	Beryllium	Manganese	Lead	Tin	Iron	Copper
Arithmetic mean	Fall 1964	6	11.1	23.7	2.8	0.11	0.0014	3.59	1.3	0.003	2.65	0.07
Maximum	Fall 1964	6	17.8	31.0	5.4	0.18	0.0028	11.00	2.7	0.01	4.3	0.15
Minimum	Fall 1964	6	5.4	17.3	0.3	0.07	0.00	0.43	0.43	0.00	1.2	0.03
Arithmetic mean	Winter 1964	14	6.3	22.0	2.0	0.09	0.0002	2.48	0.6	0.001	1.3	0.05
Maximum	Winter 1964	14	10.5	39.8	5.5	0.22	0.0010	13.00	1.4	0.01	2.7	0.09
Minimum	Winter 1964	14	4.2	13.1	0.2	0.02	0.00	0.08	0.1	0.00	0.3	0.02
Arithmetic mean	Spring 1965	6	3.5	18.2	0.9	0.075	0.00025	1.20	0.4	0.00	1.3	0.04
Maximum	Spring 1965	6	5.0	26.7	2.0	0.18	0.0008	4.50	0.6	0.00	1.7	0.07
Minimum	Spring 1965	6	2.7	12.3	0.3	0.01	0.00	0.06	0.2	0.00	0.8	0.02
Arithmetic mean	Summer 1965	6	3.7	23.7	2.7	0.06	0.0004	1.13	0.4	0.00	1.3	0.04
Maximum	Summer 1965	6	5.8	30.1	5.3	0.12	0.0010	3.20	1.0	0.00	1.9	0.08
Minimum	Summer 1965	6	1.8	18.8	0.5	0.02	0.00	0.06	0.0	0.00	0.5	0.02
Arithmetic mean	1964-1965 NASN (Nation-wide)		6.8	10.6	1.3	0.02	0.0005	0.10	0.79	0.02	1.58	0.09
Maximum	1964-1965 NASN (Nation-wide)		128.3[a]	101.2	75.5	1.00[a]	0.010	9.98	8.60	0.50	22.0	10.0
Minimum[b]	1964-1965 NASN (Nation-wide)		0.5	0.5	0.1	0.1	0.0002	0.01	0.01	0.001	0.16	0.002

Table 4-9 (continued). KANAWHA VALLEY QUARTERLY AND 1964-1965 NASN RESULTS OF CHEMICAL ANALYSES OF HIGH-VOLUME FILTER
($\mu g/m^3$)

	Sampling period	Number of station composites analyzed	Benzene-soluble fraction	Titanium	Vanadium	Zinc	Chromium	Nickel	Molybdenum	Cobalt	Bismuth	Cadmium	Antimony
Arithmetic mean	Fall 1964	6	11.1	0.10	0.008	0.98	0.028	0.032	0.003	0.007	0.0015	0.027	0.009
Maximum	Fall 1964	6	17.8	0.18	0.017	1.70	0.190	0.046	0.010	0.017	0.003	0.097	0.056
Minimum	Fall 1964	6	5.4	0.04	0.00	0.52	0.016	0.015	0.00	0.00	0.00	0.00	0.00
Arithmetic mean	Winter 1964	14	6.3	0.05	0.005	0.66	0.072	0.025	0.00	0.0005	0.0014	0.012	0.008
Maximum	Winter 1964	14	10.5	0.10	0.009	1.30	0.250	0.049	0.00	0.007	0.003	0.049	0.057
Minimum	Winter 1964	14	4.2	0.03	0.00	0.25	0.006	0.010	0.00	0.00	0.00	0.00	0.00
Arithmetic mean	Spring 1965	6	3.5	0.04	0.002	0.41	0.035	0.181	0.00	0.00	0.0015	0.00	0.00
Maximum	Spring 1965	6	5.0	0.07	0.005	0.68	0.160	1.007	0.00	0.00	0.003	0.00	0.00
Minimum	Spring 1965	6	2.7	0.01	0.00	0.24	0.005	0.01	0.00	0.00	0.00	0.00	0.00
Arithmetic mean	Summer 1965	6	3.7	0.06	0.004	0.58	0.034	0.018	0.00	0.00	0.001	0.0075	0.00
Maximum	Summer 1965	6	5.8	0.14	0.009	0.98	0.086	0.028	0.00	0.00	0.002	0.027	0.00
Minimum	Summer 1965	6	1.8	0.01	0.00	0.38	0.008	0.00	0.00	0.00	0.00	0.00	0.00
Arithmetic mean	1964-1965 NASN (Nation-wide)		6.8	0.04	0.050	0.67	0.015	0.034	0.005	0.0005	0.0005	0.002	0.001
Maximum	1964-1965 NASN (Nation-wide)		128.3[a]	1.10	2.200	58.00	0.330	0.460	0.78	0.06	0.064	0.42	0.16
Minimum[b]	1964-1965 NASN (Nation-wide)		0.5	0.0096	0.0032	0.12	0.0064	0.0064	0.0024	0.0064	0.0011	0.011	0.04

[a] Value reported in 1963 Analyses of Suspended Particulates.

[b] Lowest detectable concentrations.

Table 4-10. COMPARISON OF 1965-1965 SUSPENDED PARTICULATE RESULTS WITH WITH 1950-1951 AIR POLLUTION STUDY RESULTS
($\mu g/m^3$)

Station location	Station number	Arithmetic average		Maximum		Minimum		Manganese		Lead	
		1964-65	1950-51	1964-65	1950-51	1964-65	1950-51	1964-65 (Winter)	1950-51	1964-65 (Winter)	1950-51
Marmet	11	242	475	958	827	31	255	3.6	0.18	0.5	0.01
Kanawha City	13	267	370	1,081	641	58	69	1.1	0.16	0.8	0.12
Charleston	15	189	339	722	404	51	246	0.91	0.13	0.9	0.65
North Charleston		241	246	750	392	41	85	0.52	0.10	0.7	0.12
South Charleston		298	177	899	345	73	79	0.26	0.07	0.6	0.02
St. Albans	24	223	200	1,062	310	34	82	0.44	0.12	0.9	0.16
Nitro	25	179	353	964	712	38	131	0.28	0.21	1.4	0.18

(from 10 to 16 hours in duration) to the St. Albans and Nitro areas. This fact is also shown by the measured manganese oxide concentrations in various high-volume air sampling stations down-valley from Alloy (Table 4-11).

Table 4-11. MEASURED MANGANESE OXIDE CONCENTRATIONS DOWN-VALLEY FROM ALLOY ($\mu g/m^3$)

Station location	Station number	Ambient air measurements
Smithers	5	8.2
Cedar Grove	7	4.1
Kanawha City	13	1.7
South Charleston, E.	20	0.9
St. Albans	24	0.3
Nitro	25	0.3

Regulations[19,20] for the control of particulate emissions were proposed and presented to the West Virginia Air Pollution Control Commission. These regulations were designed to provide outdoor air containing not more than 100 $\mu g/m^3$ of suspended particulate matter (calculated as the yearly geometric mean average) at any single station and consideration was given to a 25-percent increase in industrial growth. These regulations and a description of their development are presented in Section V, Air Resource Management Program. A regulation[21] was developed by the West Virginia Air Pollution Control Commission for the study area to control the emissions from hot-mix asphalt plants and became effective on a statewide basis.

AISI Tape Sampler

Soiling particulate, or smoke shade, is collected by an AISI (American Iron and Steel Institute) sampler.[22] The particulate is collected on a filter paper tape with the air flow set at approximately 0.25 cfm. After 2 hours of operation, the sampler automatically shifts the filter paper to a new position and continues operation. The quantity of particulate collected is determined by the difference in the amount of light that can pass through the soiled spot and the unexposed filter. The results, expressed as Cohs (Coefficient or haze) per 1,000 lineal feet, give an indication of the soiling properties of the ambient air.

Results - Table 4-12 presents the quarterly geometric means, the average of these quarterly means, and the maximum quarterly average for each of the 14 sampling stations. The Smithers station had the highest value for the fall study period (1.0 Cohs) and the highest quarterly average (1.9 Cohs). The South Charleston station had the lowest overall value and the West of Nitro station the lowest maximum quarterly average. A summary of soiling data by season is presented in Tables 4-13, -14, -15, -16, and -17. Included in these seasonal summaries are the arithmetic and geometric means, the maximum values, and the frequency distribution of data. The high values of the Smithers station during the 1964 fall season were probably caused by the effect of the high particulate emissions in that area plus several local and area forest fires. No explanation is readily available for the relatively low results obtained at the South Charleston station, since a visual observation of this area indicates heavy particulate and black smoke emission. The low values reported at the West of Nitro station were expected as the area has relatively low particulate emissions.

Table 4-12. KANAWHA VALLEY SUSPENDED PARTICULATE QUARTERLY AVERAGES
(Cohs/1000 lineal ft)
(SOILING INDEX - AISI TAPE SAMPLER)

Station location	Station number	Fall 1964	Geometric mean				Average of quarterly means	Maximum quarterly average
			Winter 1965	Spring 1965	Summer 1965	Fall 1965		
Falls View	1	1.3	0.7	0.7	0.4	0.4	0.7	1.3
Smithers	5	1.9	1.2	0.6	0.6	0.5	1.0	1.9
Montgomery	6	1.8	0.9	0.7	0.5	0.7	0.7	0.9
Cedar Grove	7	0.9	0.8	0.4	0.4	0.6	0.6	0.9
Marmet	11	1.3	0.8	0.6	0.4	0.3	0.7	1.3
Kanawha City	13	N.m.[a]	0.7	0.6	0.6	N.m.[a]	0.6	0.7
Charleston	15	0.7	0.8	0.8	0.6	0.9	0.8	0.9
West Charleston	17	0.8	0.7	0.5	0.4	0.6	0.6	0.8
North Charleston, West	19	0.9	1.1	0.6	0.4	0.7	0.7	1.1
South Charleston, East	20	0.6	0.5	0.4	0.3	0.4	0.4	0.6
Dunbar	22	0.6	0.6	0.4	0.3	0.4	0.5	0.6
St. Albans	24	0.8	0.7	0.4	0.3	0.4	0.5	0.8
Nitro	25	0.7	0.6	0.4	0.4	0.5	0.5	0.7
West of Nitro	27	N.m.[a]	N.m.[a]	0.6	0.5	0.5	0.5	0.6

[a] Not measured.

Table 4-13. KANAWHA VALLEY SUSPENDED PARTICULATE RESULTS - FALL 1964
(Cohs/100 lineal ft)
(SOILING INDEX - AISI TAPE SAMPLER)

Station location	Station number	Arithmetic mean	Geometric mean	Maximum	Minimum	Frequency distribution			
						10%	50%	90%	99%
Falls View	1	1.7	1.3	6.6	0.1[a]	0.4	1.3	3.3	5.6
Smithers	5	0.7	1.9	11.6	0.2	0.6	2.0	5.4	10.6
Montgomery	6	1.1	0.8	4.3	0.1[a]	0.1	0.8	2.7	3.7
Cedar Grove	7	0.2	0.9	4.7	0.1[a]	0.2	1.0	2.7	4.3
Marmet	11	0.9	1.3	6.8	0.1[a]	0.3	1.5	4.0	6.3
Charleston	15	1.0	0.7	3.6	0.1[a]	0.2	0.6	2.4	3.3
West Charleston	17	1.2	0.8	4.7	0.1[a]	0.3	0.9	2.5	4.0
North Charleston, W.	19	1.3	0.9	6.1	0.1[a]	0.3	0.8	3.2	5.0
South Charleston, E.	20	0.8	0.6	3.5	0.1[a]	0.1	0.6	1.9	3.5
Dunbar	22	0.7	0.6	5.4	0.1[a]	0.2	0.6	1.4	3.2
St. Albans	24	1.1	0.8	5.0	0.1[a]	0.3	0.8	2.4	4.1
Nitro	25	0.9	0.7	5.0	0.1[a]	0.2	0.7	2.1	3.5

[a] Less than 0.1 Cohs/1000 lineal ft

Table 4-14. KANAWHA VALLEY SUSPENDED PARTICULATE RESULTS - WINTER 1964-1965
(Cohs/1000 lineal ft)
(SOILING INDEX - AISI TAPE SAMPLER)

Station location	Station number	Arithmetic mean	Geometric mean	Maximum	Minimum[a]	Frequency distribution			
						10%	50%	90%	99%
Falls View	1	0.8	0.8	2.8	0.1	0.3	0.8	1.4	2.0
Smithers	5	1.5	1.2	8.7	0.1	0.3	1.3	3.0	4.7
Montgomery	6	1.2	0.9	4.2	0.1	0.2	1.1	2.4	3.5
Cedar Grove	7	1.0	0.8	5.9	0.1	0.3	0.8	2.2	3.8
Marmet	11	1.1	0.8	4.4	0.1	0.2	0.8	2.4	3.6
Kanawha City	13	1.0	0.7	3.7	0.1	0.3	0.7	2.2	3.6
Charleston	15	1.1	0.8	5.4	0.1	0.2	0.8	2.5	4.2
West Charleston	17	0.9	0.7	4.0	0.1	0.2	0.6	2.0	3.3
North Charleston, West	19	1.3	1.1	5.3	0.1	0.4	1.0	2.6	4.7
South Charleston, East	20	0.7	0.5	3.7	0.1	0.1	0.5	1.5	2.7
Dunbar	22	0.8	0.6	5.3	0.1	0.2	0.6	1.7	3.4
St. Albans	24	0.9	0.7	4.7	0.1	0.2	0.7	2.1	3.3
Nitro	25	0.7	0.6	3.5	0.1	0.2	0.5	1.6	2.6

[a] Less than 0.1 Cohs/1000 lineal ft.

Table 4-15. KANAWHA VALLEY SUSPENDED PARTICULATE RESULTS - SPRING 1965
(Cohs/1000 lineal ft)
(SOILING INDEX - AISI TAPE SAMPLER)

Station location	Station number	Arithmetic mean	Geometric mean	Maximum	Minimum[a]	Frequency distribution			
						10%	50%	90%	99%
Falls View	1	0.8	0.7	6.3	0.1	0.3	0.7	1.6	3.0
Smithers	5	0.9	0.6	6.1	0.1	0.2	0.6	2.0	3.4
Montgomery	6	1.0	0.7	6.6	0.1	0.2	0.7	2.2	4.1
Cedar Grove	7	0.6	0.4	3.6	0.1	0.1	0.4	1.1	2.4
Marmet	11	0.7	0.6	4.7	0.1	0.2	0.6	1.4	2.4
Kanawha City	13	0.8	0.6	3.4	0.1	0.2	0.7	1.6	2.5
Charleston	15	1.1	0.8	4.3	0.1	0.3	0.8	2.1	3.6
West Charleston	17	0.6	0.5	2.8	0.1	0.1	0.5	1.2	2.3
North Charleston, W.	19	0.7	0.6	3.7	0.1	0.2	0.6	1.4	2.6
South Charleston, E.	20	0.5	0.4	2.6	0.1	0.1	0.4	1.1	2.5
Dunbar	22	0.5	0.4	2.7	0.1	0.1	0.4	1.1	2.2
St. Albans	24	0.5	0.4	3.9	0.1	0.1	0.4	1.2	2.6
Nitro	25	0.5	0.4	2.9	0.1	0.1	0.4	0.9	2.2
West of Nitro	27	0.7	0.6	4.0	0.1	0.1	0.7	1.5	2.2

[a] Less than 0.1 Cohs/1000 lineal ft.

Table 4-16. KANAWHA VALLEY SUSPENDED PARTICULATE RESULTS - SUMMER 1965
(Cohs/1000 lineal ft)
(SOILING INDEX - AISI TAPE SAMPLER)

Station location	Station number	Arithmetic mean	Geometric mean	Maximum	Minimum[a]	Frequency distribution			
						10%	50%	90%	99%
Falls View	1	0.5	0.4	3.6	0.1	0.2	0.6	1.6	2.3
Smithers	5	0.8	0.6	4.3	0.1	0.2	0.7	1.7	2.4
Montgomery	6	0.7	0.5	5.0	0.1	0.1	0.4	1.6	3.9
Cedar Grove	7	0.5	0.4	2.4	0.1	0.1	0.4	1.1	1.9
Marmet	11	0.5	0.4	3.4	0.1	0.1[a]	0.4	0.9	1.9
Kanawha City	13	0.7	0.6	2.9	0.1	0.2	0.6	1.3	2.0
Charleston	15	0.8	0.6	2.8	0.1	0.2	0.6	1.6	2.3
West Charleston	17	0.4	0.4	1.6	0.1	0.1	0.4	0.8	1.3
North Charleston, W.	19	0.5	0.4	2.4	0.1	0.1	0.4	1.0	1.6
South Charleston, E.	20	0.3	0.3	1.4	0.1	0.1[a]	0.3	0.7	1.2
Dunbar	22	0.4	0.3	1.7	0.1	0.1	0.3	0.7	1.4
St. Albans	24	0.4	0.3	2.2	0.1	0.1	0.3	0.8	1.2
Nitro	25	0.4	0.4	4.2	0.1	0.1	0.4	0.8	1.2
West of Nitro	27	0.6	0.5	2.6	0.1	0.1	0.5	1.3	1.8

[a] Less than 0.1 Cohs/1000 lineal ft.

Table 4-17. KANAWHA VALLEY SUSPENDED PARTICULATE RESULTS - FALL 1965

(Cohs/1000 lineal ft)
(SOILING INDEX - AISI TAPE SAMPLER)

Station location[a]	Station number	Arithmetic mean	Geometric mean	Maximum	Minimum[b]	Frequency distribution			
						10%	50%	90%	99%
Falls View	1	0.5	0.4	2.4	0.1	0.1	0.4	1.0	1.8
Smithers	5	0.7	0.5	2.8	0.1	0.1	0.6	1.4	2.2
Montgomery	6	0.9	0.7	4.3	0.1	0.2	0.7	1.9	3.7
Cedar Grove	7	0.8	0.6	3.5	0.1	0.2	0.7	1.6	2.5
Marmet	11	0.4	0.3	3.4	0.1	0.1[b]	0.2	1.2	2.6
Charleston	15	1.3	0.9	4.8	0.1	0.3	0.9	2.8	3.9
West Charleston	17	0.9	0.6	4.3	0.1	0.2	0.7	2.0	3.1
North Charleston, W.	19	0.9	0.7	8.2	0.1	0.2	0.7	1.7	2.9
South Charleston, E.	20	0.5	0.4	4.7	0.1	0.1	0.3	1.0	3.2
Dunbar	22	0.6	0.4	3.0	0.1	0.2	0.4	1.1	2.4
St. Albans	24	0.6	0.4	2.9	0.1	0.1	0.4	1.3	2.3
Nitro	25	0.6	0.5	2.6	0.1	0.1	0.5	1.3	2.2
West of Nitro	27	0.6	0.5	3.9	0.1	0.1	0.5	1.4	2.4

[a] Kanawha City station was not operating.

[b] Less than 0.1 Cohs/1000 lineal ft.

A review of the diurnal variation of the AISI sampler results, Table 4-18, indicates that the period from 6:00 to 8:00 a.m. has the highest values while the 2:00 to 4:00 p.m. period has the lowest reported values. This indicates that the higher values occur while morning inversions are limiting the upward dispersion of the pollutants. The lower concentrations obtained during the afternoon, from 2:00 to 4:00 p.m., indicate the lower pollution levels brought about by the flushing of the Kanawha Valley by the daytime winds.

The study data were compared with adopted and proposed air quality criteria or standards. A compilation of these standards or criteria is presented in Table 4-19. A comparison of the study results with these standards or criteria is presented in Figure 4-5. All the stations exceeded the proposed St. Louis maximum permissible concentration (0.4 Cohs per 1000 lineal feet, annual geometric mean) and the Colorado standard (0.5 Cohs per 1000 lineal feet, average for any three-month period). The average of five Kanawha Valley quarterly means was used in place of the annual geometric mean for comparison with the St. Louis standard. All the reported averages were rated as "light soiling" by the New Jersey rating system[23] or "moderate soiling" if the maximum quarterly averages were used. The study staff understands that the New Jersey system is being revised.

A comparison of the soiling index data obtained with existing standards or criteria indicates that this particular contaminant is a problem in the Kanawha Valley. A formally expressed degree of the problem depends upon the air pollution standards or criteria selected for the study area. Significant reductions in both soiling and haze should result from the implementation of Regulation II[19] - for the control of smoke and particulate emissions from indirect heat exchangers or boilers. The adoption of regulations for the control of process particulate emissions[20] will also be required for the reduction of soiling values in the Alloy area, as a major portion of the particulates measured in that area by an AISI tape sampler are probably due to process emissions.

Settleable Particulate (Dustfall)

Settleable particulate matter, commonly called "dustfall,"[26] was measured at 27 fixed sampling stations in the study area. Primarily the combustion of solid fuels is the source of these emissions in the Kanawha Valley. Additional sources are metallurgical operations, asphalt hot-mix plants, and other similar processes. In most cases, these sources have inadequate air pollution control equipment.

Settleable particulate matter is not generally considered to be a significant health hazard, as the particle size is usually too large for inhalation into

Table 4-18. DIURNAL VARIATION KANAWHA VALLEY SUSPENDED PARTICULATE RESULTS, AISI TAPE SAMPLERS
(Cohs/1000 lineal ft)

Station location	Station number	Season	Time											
			0000	0200	0400	0600	0800	1000	1200	1400	1600	1800	2000	2200
Charleston	15	Fall 1964	1.1	1.1	1.1	1.1	1.1	1.0	0.7	0.7	0.7	0.9	1.1	1.0
		Winter 1965	1.2	1.3	1.4	1.4	1.4	1.2	0.7	0.6	0.6	0.9	1.0	1.1
		Spring 1965	1.3	1.4	1.6	1.7	1.3	0.8	0.6	0.5	0.6	0.8	1.1	1.3
		Summer 1965	1.1	1.0	1.1	1.1	0.7	0.5	0.4	0.4	0.5	0.6	0.6	1.0
		Fall 1965	1.4	1.5	1.5	1.5	1.3	1.1	1.1	1.0	1.1	1.3	1.2	1.4
		Average	1.2	1.2	1.3	1.4	1.2	0.9	0.7	0.6	0.7	0.9	1.1	1.1
Falls View	1	Fall 1964	1.7	2.0	2.0	2.0	2.0	1.8	1.6	1.4	1.4	1.3	1.7	1.7
		Winter 1965	0.8	0.8	0.9	0.9	0.9	0.9	0.8	0.8	0.8	0.8	0.8	0.8
		Spring 1965	1.0	1.0	1.0	1.0	1.0	0.9	0.7	0.7	0.6	0.6	0.8	0.9
		Summer 1965	0.6	0.6	0.6	0.5	0.6	0.5	0.5	0.4	0.4	0.5	0.6	0.6
		Fall 1965	0.6	0.6	0.6	0.6	0.7	0.6	0.5	0.4	0.4	0.5	0.5	0.6
		Average	0.9	1.0	1.0	1.0	1.0	0.9	0.8	0.7	0.7	0.7	0.9	0.9
Smithers	5	Fall 1964	2.5	2.8	3.0	3.1	3.3	3.8	3.1	1.9	1.9	2.2	2.3	2.4
		Winter 1965	1.5	1.5	1.8	1.9	1.8	1.8	1.4	1.1	1.3	1.3	1.5	1.6
		Spring 1965	1.0	1.1	1.2	1.5	1.5	0.9	0.5	0.4	0.4	0.5	0.7	0.8
		Summer 1965	1.1	1.1	1.1	1.1	0.9	0.6	0.4	0.4	0.5	0.7	0.9	1.0
		Fall 1965	0.9	0.8	0.8	0.8	0.7	0.6	0.5	0.5	0.6	0.6	0.7	0.7
		Average	1.4	1.5	1.6	1.7	1.6	1.5	1.2	0.9	1.0	1.1	1.2	1.3
Montgomery	6	Fall 1964	1.0	1.2	1.3	1.5	1.7	1.3	0.9	0.8	0.6	0.9	1.0	1.0
		Winter 1965	1.1	1.1	1.3	1.6	1.8	1.5	1.0	0.7	0.8	1.1	1.1	1.2
		Spring 1965	1.1	1.3	1.6	1.9	1.6	0.8	0.5	0.4	0.5	0.7	0.9	0.9
		Summer 1965	0.6	0.7	1.0	1.1	1.1	0.7	0.4	0.4	0.4	0.5	0.5	0.5
		Fall 1965	1.0	1.0	0.9	1.0	1.1	0.9	0.7	0.6	0.8	0.9	0.8	0.9
		Average	1.0	1.1	1.2	1.4	1.5	1.1	0.7	0.6	0.6	0.8	0.9	0.9

Table 4-18 (continued). DIURNAL VARIATION KANAWHA VALLEY SUSPENDED PARTICULATE RESULTS, AISI TAPE SAMPLERS
(Cohs/1000 lineal ft)

Station location	Station number	Season	Time											
			0000	0200	0400	0600	0800	1000	1200	1400	1600	1800	2000	2200
Cedar Grove	7	Fall 1964	1.2	1.2	1.3	1.4	1.5	1.4	1.1	1.0	1.1	1.2	1.1	1.0
		Winter 1965	0.9	1.0	0.9	1.1	1.4	1.4	1.0	0.7	0.9	1.0	1.0	0.9
		Spring 1965	0.5	0.6	0.7	1.0	1.0	0.5	0.3	0.4	0.4	0.5	0.5	0.4
		Summer 1965	0.5	0.6	0.7	0.8	0.8	0.5	0.4	0.4	0.4	0.4	0.5	0.4
		Fall 1965	0.7	0.8	0.9	1.0	1.0	1.0	0.7	0.6	0.6	0.6	0.7	0.7
		Average	0.8	0.8	0.9	1.0	1.1	0.9	0.7	0.6	0.7	0.7	0.7	0.7
Marmet Elementary School	11	Fall 1964	2.1	2.0	2.0	2.0	2.0	1.9	1.5	1.3	1.7	1.9	2.0	2.3
		Winter 1965	1.2	1.2	1.2	1.3	1.4	1.2	0.7	0.7	0.8	1.0	1.0	1.1
		Spring 1965	0.8	0.8	0.8	1.0	0.9	0.5	0.4	0.5	0.5	0.7	0.8	0.8
		Summer 1965	0.5	0.6	0.6	0.6	0.5	0.3	0.3	0.3	0.4	0.4	0.5	0.5
		Fall 1965	0.6	0.5	0.5	0.5	0.4	0.3	0.4	0.5	0.4	0.5	0.5	0.5
		Average	1.0	1.0	1.0	1.1	1.1	0.9	0.7	0.6	0.8	0.9	1.0	1.0
Horace Mann School		Winter 1965	1.0	1.1	1.2	1.0	1.2	0.8	0.8	0.9	0.8	0.9	1.0	1.1
		Spring 1965	1.0	1.1	1.1	1.2	1.0	0.6	0.4	0.4	0.4	0.6	0.9	1.0
		Summer 1965	0.9	0.9	0.9	0.9	0.6	0.4	0.4	0.4	0.4	0.6	0.8	0.9
		Average	1.0	1.1	1.1	1.0	0.9	0.6	0.6	0.6	0.6	0.6	0.9	1.0
Glenwood Elementary School		Fall 1964	1.1	1.2	1.3	1.4	1.3	1.2	1.0	0.9	1.0	1.1	1.1	1.1
		Winter 1965	0.9	1.0	0.9	1.0	1.1	0.9	0.7	0.7	0.7	0.9	0.9	0.9
		Spring 1965	0.7	0.7	0.7	0.8	0.8	0.5	0.4	0.5	0.5	0.5	0.8	0.7
		Summer 1965	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.3	0.3	0.3	0.5	0.5
		Fall 1965	1.1	1.1	0.8	0.9	1.1	0.9	0.7	0.6	0.7	0.9	1.0	1.1
		Average	0.9	0.9	0.9	0.9	0.9	0.8	0.6	0.6	0.7	0.8	0.9	0.9

Table 4-18 (continued). DIURNAL VARIATION KANAWHA VALLEY SUSPENDED PARTICULATE RESULTS, AISI TAPE SAMPLERS
(Cohs/1000 lineal ft)

Station location	Station number	Season	Time											
			0000	0200	0400	0600	0800	1000	1200	1400	1600	1800	2000	2200
North Charleston Fire Station		Fall 1964	1.3	1.3	1.3	1.7	1.6	1.4	1.3	1.2	1.1	1.2	1.1	1.2
		Winter 1965	1.2	0.9	1.5	1.7	1.8	1.6	1.0	0.9	1.0	1.2	1.2	1.2
		Spring 1965	0.7	0.7	0.8	1.0	1.0	0.7	0.7	0.7	0.7	0.7	0.7	0.6
		Summer 1965	0.5	0.5	0.6	0.8	0.7	0.5	0.4	0.4	0.4	0.4	0.4	0.5
		Fall 1965	0.7	0.7	0.9	1.0	1.0	0.9	0.8	0.8	0.8	0.9	0.9	0.8
		Average	0.9	0.8	1.0	1.2	1.2	1.0	0.9	0.8	0.8	0.9	0.9	0.9
South Charleston		Fall 1964	0.8	0.7	0.9	1.0	0.8	0.8	0.8	0.7	0.7	0.8	0.9	0.8
		Winter 1965	0.7	0.7	0.7	0.8	0.9	0.9	0.6	0.5	0.5	0.5	0.6	0.7
		Spring 1965	0.6	0.6	0.6	0.8	0.8	0.7	0.4	0.3	0.3	0.3	0.3	0.4
		Summer 1965	0.4	0.4	0.4	0.5	0.5	0.3	0.2	0.2	0.2	0.2	0.3	0.3
		Fall 1965	0.4	0.4	0.4	0.4	0.5	0.6	0.6	0.4	0.4	0.5	0.4	0.4
		Average	0.6	0.6	0.6	0.7	0.7	0.6	0.5	0.4	0.4	0.5	0.5	0.5
Alban Elementary School		Fall 1964	1.0	1.0	1.1	1.3	1.4	1.4	1.2	0.8	0.7	0.9	1.0	1.1
		Winter 1965	1.0	1.1	1.0	1.0	1.0	0.9	0.7	0.7	0.8	1.0	1.0	1.1
		Spring 1965	0.7	0.7	0.7	0.8	0.6	0.4	0.3	0.3	0.4	0.5	0.7	0.7
		Summer 1965	0.4	0.4	0.4	0.5	0.4	0.3	0.3	0.2	0.2	0.3	0.5	0.4
		Fall 1965	0.6	0.6	0.7	0.8	0.9	0.6	0.4	0.3	0.4	0.5	0.5	0.6
		Average	0.8	0.8	0.8	0.9	0.8	0.7	0.6	0.5	0.5	0.7	0.7	0.8
Ford Elementary School		Fall 1964	0.8	0.7	0.7	0.8	1.0	0.9	0.6	0.6	0.6	0.7	0.7	0.8
		Winter 1965	0.9	0.9	0.9	0.9	0.9	0.9	0.6	0.6	0.7	0.8	0.9	0.9
		Spring 1965	0.6	0.6	0.6	0.9	0.7	0.4	0.3	0.3	0.3	0.4	0.6	0.6
		Summer 1965	0.4	0.5	0.5	0.5	0.4	0.3	0.3	0.3	0.3	0.3	0.4	0.4
		Fall 1965	0.6	0.7	0.6	0.6	0.7	0.7	0.4	0.4	0.4	0.5	0.6	0.6
		Average	0.6	0.7	0.7	0.7	0.7	0.7	0.4	0.4	0.5	0.6	0.6	0.6

Table 4-18 (continued). DIURNAL VARIATION KANAWHA VALLEY SUSPENDED PARTICULATE RESULTS, AISI TAPE SAMPLERS
(Cohs/1000 lineal ft)

Station location	Station number	Season	Time											
			0000	0200	0400	0600	0800	1000	1200	1400	1600	1800	2000	2200
Nitro Junior High School		Fall 1964	0.9	0.9	1.0	1.2	1.3	1.1	0.8	0.6	0.6	0.8	0.8	1.0
		Winter 1965	0.9	0.8	0.9	0.9	0.7	0.6	0.5	0.5	0.6	0.7	0.8	0.9
		Spring 1965	0.5	0.5	0.6	0.7	0.6	0.4	0.3	0.3	0.4	0.4	0.5	0.5
		Summer 1965	0.4	0.5	0.5	0.5	0.4	0.4	0.3	0.3	0.3	0.4	0.5	0.5
		Fall 1965	0.6	0.7	0.7	0.8	0.7	0.6	0.5	0.4	0.4	0.5	0.5	0.6
		Average	0.7	0.7	0.7	0.8	0.8	0.6	0.5	0.4	0.5	0.6	0.6	0.7
Craft's Farm		Spring 1965	1.1	1.1	1.0	0.8	0.8	0.5	0.4	0.3	0.4	0.6	0.9	1.0
		Summer 1965	0.9	0.8	0.8	0.6	0.6	0.4	0.3	0.3	0.4	0.6	0.8	0.9
		Fall 1965	0.7	0.7	0.7	0.8	0.8	0.6	0.5	0.4	0.5	0.5	0.6	0.6
		Average	0.9	0.9	0.8	0.7	0.7	0.5	0.4	0.4	0.5	0.6	0.8	0.8

Table 4-19. SUSPENDED PARTICULATE (SOILING INDEX) AMBIENT AIR QUALITY STANDARDS OR CRITERIA FOR UNITED STATES, 1966

Colorado[6] - 0.5 Cohs/1000 lineal feet, average for any 3-month period.

New Jersey Rating System[23]

0 - 0.9 Cohs/1000 lineal feet	Light soiling
1.0 - 1.9 Cohs/1000 lineal feet	Moderate soiling
2.0 - 2.9 Cohs/1000 lineal feet	Heavy soiling
3.0 - 3.9 Cohs/1000 lineal feet	Very heavy soiling
4.0 - plus Cohs/1000 lineal feet	Extremely heavy soiling

St. Louis[10] (Metropolitan Area)[1], maximum permissible concentration.

0.4 Cohs/1000 lineal feet, annual geometric mean.

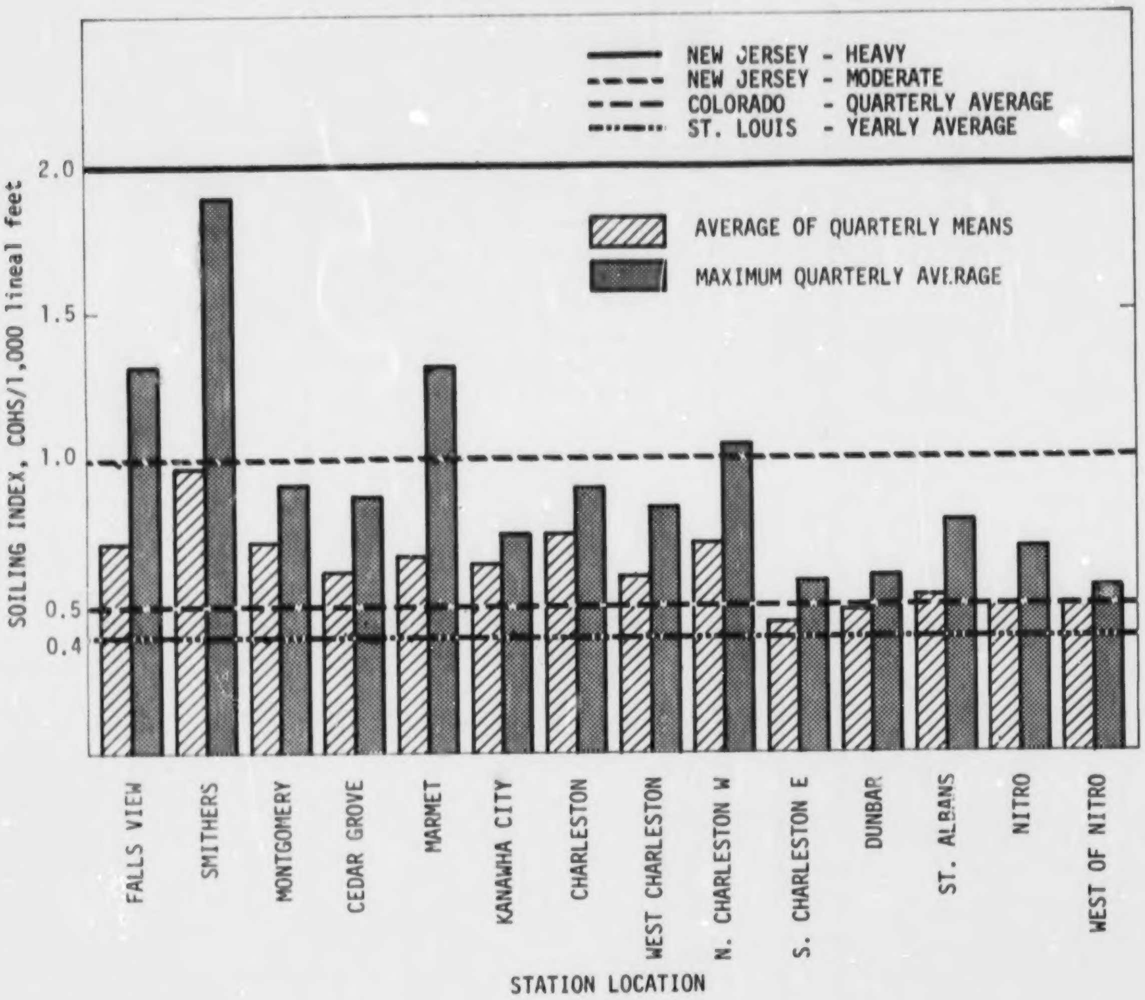


Figure 4-5. Comparison of Kanawha Valley suspended particulate results with various standards.

the respiratory system. The large amount of dustfall in the South Charleston, Montgomery Heights, Boomer, and Smithers areas is a noticeable soiling and nuisance problem, however.

Method - Dustfall is measured by exposing wide-mouth containers in suitable stands on a roof or other support for a period of 1 month. The jars are covered after the exposure period and returned to the laboratory, where the total dustfall is determined gravimetrically. The samples obtained in the study area were also analyzed for both the water soluble and insoluble portions. The results were reported as tons per square mile per month (tons/mi^2-mo) of water soluble, water insoluble and total dustfall. Composite samples of the insoluble portion obtained from nine stations were analyzed for metals content.

Results - A summary of the dustfall results for the period of October 1964 through December 1965 are reported in Table 4-20. The arithmetic and geometric means, maximum and minimum values, and quarterly averages are reported in this summary. The average geometric mean value for the entire study area was reported as 42 tons/mi^2-mo, the maximum and minimum geometric means were 175 (Montgomery Heights) and 11 (Crede) tons/mi^2-mo, respectively. The maximum single monthly value of 468 tons/mi^2-mo was reported at the Boomer station and the next greatest value of 318 tons/mi^2-mo was reported at the Montgomery Heights station. The maximum quarterly average of 222 tons/mi^2-mo was reported at the Boomer station. The Montgomery Heights and Boomer stations are located in the Alloy area - Montgomery Heights to the east, Boomer to the west, and downriver from the ferro-alloy plant. In addition to the electric furnaces, a large coal-fired power plant is located at the ferro-alloy plant. A large coal preparation plant is located downriver from the Boomer station. Another source that may be contributing significantly to the dustfall at these stations is refuse burning in this area. Other localities which reported very large dustfall measurements were the South and North Charleston areas, with South Charleston East at 90, North Charleston West at 68, and North Charleston East at 63 tons/mi^2-mo. These stations are located within 1/2-mile of the South Charleston chemical complex.

Monthly and seasonal dustfall averages are presented in Figure 4-6. These averages show that the winter quarter of 1965 had the highest dustfall followed by the spring quarter of 1965. The quarterly averages for the fall of 1965 and the winter of 1966 are essentially the same, indicating that meteorological factors permitted the dispersion or ventilation of the larger amounts of pollutants emitted in the winter time.

Table 4-20. KANAWHA VALLEY SETTLED PARTICULATES VALUES
(tons/mi^2-mo)

Station location	Station number	Arithmetic mean	Geometric mean	Maximum value	Minimum value	Maximum quarterly average
Falls View	1	34	31	51	13	51
Montgomery Heights	2	191	175	319	77	222
Kimberly	3	68	61	102	17	87
Boomer	4	123	100	468	47	215
Smithers	5	89	82	121	28	121
Montgomery	6	55	54	76	27	67
Cedar Grove	7	38	32	117	14	61
Chelyan	8	26	25	39	12	38
Chesapeake	9	26	24	58	10	33
Belle	10	25	19	83	4	43
Marmet	11	30	29	48	12	29
South Malden	12	27	25	44	11	41
Kanawha City	13	22	21	37	11	31
East Charleston	14	17	12	34	1	30
Charleston	15	21	19	170	7	96
Crede	16	17	11	54	2	26
West Charleston	17	31	28	53	14	47
North Charleston, E.	18	67	63	122	41	91
North Charleston, W.	19	68	68	120	42	84
South Charleston, E.	20	92	90	147	62	119
South Charleston, W.	21	24	21	61	9	36
Dunbar	22	25	21	44	5	41
Institute	23	54	41	193	18	73
St. Albans	24	24	22	45	6	38
Nitro	25	27	17	138	6	59
West of St. Albans	26	24	23	49	6	27
West of Nitro	27	24	20	57	6	32

The measured amounts of dustfall in the study area were compared with several adopted and proposed air quality standards and objectives around the country. A summary of these standards and objectives is presented in Table 4-21. Figure 4-7 is a comparision of the study area data with these standards or objectives. The study area stations exceeded the proposed St. Louis standard (15 tons/mi^2-mo, 3 months average) for residential areas. All but five stations - Crede, East Charleston, Charleston, Nitro, and Belle - exceeded the Oregon standards for residential or commercial areas (15 tons/mi^2-mo above background) and all but three stations - Crede, East Charleston, and West of St. Albans - exceeded the proposed St. Louis standard (30 tons/mi^2-mo, 3 months average) for heavy industrial areas. Nine stations, five in the Alloy area, three in the South-North Charleston area and the single station at Institute exceeded the Oregon standard (30 tons/mi^2-mo, above

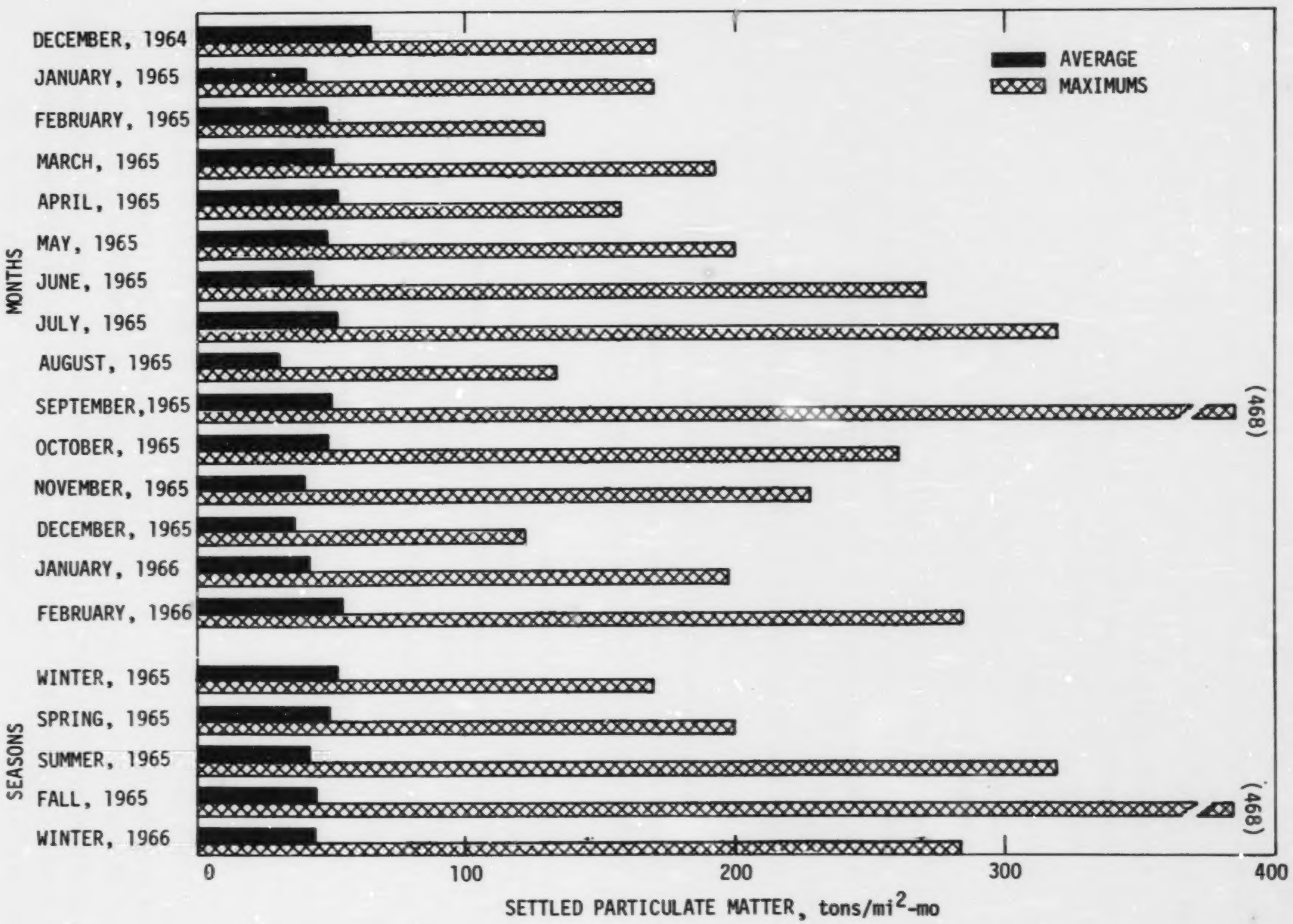


Figure 4-6. Kanawha Valley settled particulate matter, maximums, monthly and seasonal averages.

Table 4-21. SETTLED PARTICULATE AMBIENT AIR QUALITY STANDARDS AND OBJECTIVES IN THE UNITED STATES, 1966

New York State[7] - Objectives vary according to regions and subregions

- Regional Objective C
  - Subregion 3 - 25.7 tons/mi^2-mo, <50% of values
  - Subregion 4 - 34.3 tons/mi^2-mo, <50% of values
- Regional Objective D
  - Subregion 3 - 34.3 tons/mi^2-mo, <50% of values
  - Subregion 4 - 42.8 tons/mi^2-mo, <50% of values

Oregon[8] - Concentration shall not exceed the stated value plus normal background

- Residential or commercial - 15 tons/mi^2-mo above normal background
- Heavy industrial areas - 30 tons/mi^2-mo above normal background

Pennsylvania[9] -

- Maximum outside own property, calculated using diffusion equations- 17.1 tons/mi^2-mo

St. Louis[10] (Metropolitan Area) - Maximum permissible concentrations

- 3-month average in residential areas - 15 tons/mi^2-mo
- 3-month average in heavy industrial areas - 30 tons/mi^2-mo

normal background) for heavy industrial areas and the New York Region C, Subregion 4 and Region D, Subregion 3 (34.3 tons/mi^2-mo, <50 percent of values). The eight stations in the Alloy and South-North Charleston areas exceeded the New York objective for Region D, Subregion 4 or the dirtiest area projected for that state. New York Region D, Subregion 4 objective is for a heavy industrial area in either the New York City or Buffalo areas, while all of the Kanawha Valley stations were located in either residential or commercial-residential areas. Mention should be made of the fact that the residential, commercial, and industrial areas in the Kanawha Valley are generally not isolated, but are quite often adjacent to, or intermixed with, one another.

The results of analyses of composite samples of the insoluble portion of study area dustfall results are presented in Table 4-22. Significant concentrations of metals were obtained mainly from the stations in the Alloy, Smithers, and Montgomery areas. As expected, the Smithers area had the largest reported manganese and chromium measurements, while the Montgomery stations had the largest reported measurements of lead, tin, iron, copper, and titanium. The Nitro station had the largest reported percentage of nickel.

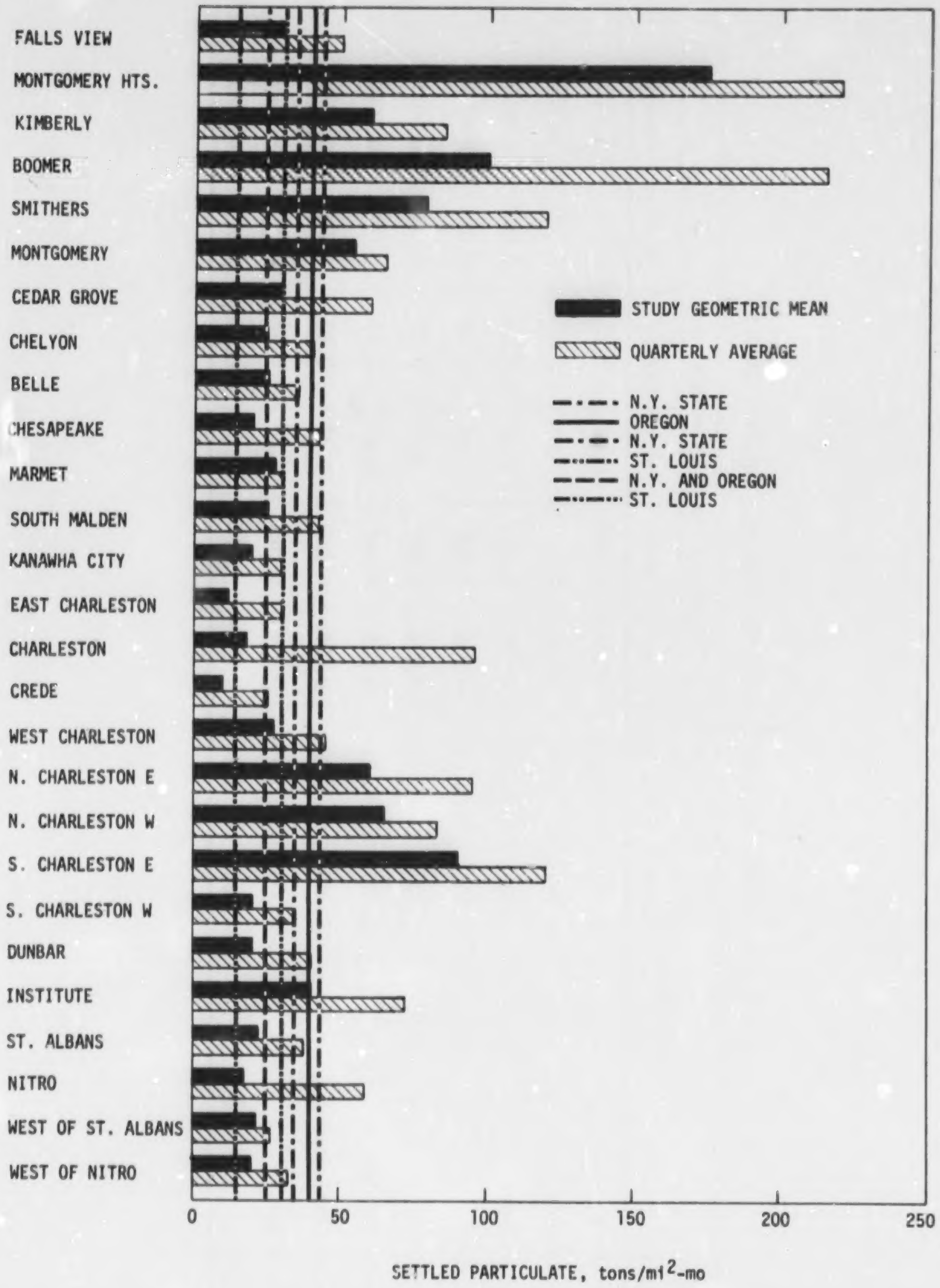


Figure 4-7. Comparison of Kanawha Valley settled particulate results with air quality standards or criteria.

Table 4-22. METALS ANALYSIS OF SELECTED INSOLUBLE DUSTFALL SAMPLES

Station location	Station number	Metals, percent by weight							
		Barium	Manganese	Lead	Tin	Iron	Copper	Titanium	Vanadium
Smithers	5	0.0007	0.62	0.036	0.005	0.40	2.20	0.022	0.0029
Montgomery	6	0.0007	0.14	0.036	0.11	7.8	3.6	0.028	0.0029
Cedar Grove	7	0.0007	0.01	0.036	0.02	0.23	0.09	0.002	0.0029
Marmet	11	0.0007	0.01	0.036	0.005	0.68	0.14	0.009	0.0029
Kanawha City	13	0.0007	0.01	0.036	0.005	0.52	0.17	0.008	0.0029
North Charleston		0.0007	0.01	0.036	0.005	0.43	0.11	0.029	0.0029
South Charleston		0.0007	0.01	0.036	0.005	0.32	0.10	0.032	0.0029
St. Albans	24	0.0007	0.01	0.036	0.005	0.24	0.39	0.007	0.0029
Nitro	25	0.0007	0.01	0.036	0.005	0.14	0.038	0.0037	0.0029

Table 4-22 (continued). METALS ANALYSIS OF SELECTED INSOLUBLE DUSTFALL SAMPLES

		Metals, percent by weight							
Station location	Station number	Zinc	Chromium	Nickel	Molybdenum	Cobalt	Bismuth	Cadmium	Antimony
Smithers	5	0.19	0.012	0.0057	0.0022	0.0057	0.001	0.01	0.036
Montgomery	6	0.19	0.00	0.018	0.0022	0.0057	0.001	0.01	0.036
Cedar Grove	7	0.19	0.005	0.0057	0.0022	0.0057	0.001	0.01	0.036
Marmet	11	0.19	0.005	0.0057	0.0022	0.0057	0.001	0.01	0.036
Kanawha City	13	0.19	0.005	0.0057	0.0022	0.0057	0.001	0.01	0.036
North Charleston		0.19	0.005	0.0057	0.0022	0.0057	0.001	0.01	0.036
South Charleston		0.19	0.005	0.0057	0.0022	0.0057	0.001	0.01	0.036
St. Albans	24	0.19	0.005	0.0057	0.0022	0.0057	0.001	0.01	0.036
Nitro	25	0.19	0.005	0.019	0.0022	0.0057	0.001	0.01	0.036

A comparison of this study's dustfall measurements with the 1950-57 Kanawha Valley study measurements is presented in Table 4-23. All but two of the comparable stations reported a reduction in average distfall. The Smithers station indicated a slight average increase and the Nitro station indicated practically no average change. Reductions in the study periods' averages of approximately 50 percent or more were reported for Kanawha City (68 percent), Marmet (65 percent), Montgomery (49 percent), with other significant reductions for South Charleston (37 percent), Cedar Grove (34 percent), and North Charleston (33 percent). The metals analyses of the 1950-57 dustfall samples also indicated that dustfall in the Alloy area, as expected, had the greatest metals concentrations.

The adoption and resulting corrective action of regulations covering particulates can be expected to bring about a greater improvement in settleable particulates than in suspended particulates at most sampling areas. This should occur because collectors and other control methods are generally more effective in removing larger size particles (dustfall) than the smaller size particles (suspended particulates).

Sulfation Rate (Lead Peroxide Candle)

Sulfur oxides and other sulfur compounds were measured at 27 fixed sampling sites with lead peroxide candles. The sources of sulfur oxides are the combustion of fuels, mainly coal; industrial processes, such as sulfuric acid manufacturing plants; the disposal of wastes, such as the flaring (burning) of organic or inorganic sulfur compounds, and other small emission sources. The measurement of these compounds is of interest due to their harmful effects on the health of humans and animals; damage to vegetation; deterioration of materials such as metals, stonework, fabrics, paper, etc.; and reduction in visibility.

Method - The sampler consisted of a cylinder wrapped with a gauze coated with lead peroxide.[25] Sulfur oxides and other sulfur compounds in the air, such as mercaptans, hydrogen sulfide, etc., react with the lead peroxide to form lead sulfate. The candles are exposed in an appropriate shelter for a period of 1 month and then analyzed for sulfate content. The results are usually expressed in milligrams of sulfur trioxide per 100 square centimeters per day (mg SO_3/100 cm^2-day). Because the reactivity of lead peroxide varies from one batch to another, sufficient lead peroxide was obtained for the entire study. Further, in order that the study results could be compared and correlated with results in other areas, the batch of lead peroxide was standardized against a standard lead peroxide candle purchased

Table 4-23. COMPARISON OF 1964-65 DUSTFALL RESULTS WITH 1950-51 AIR POLLUTION STUDY RESULTS

Station location	Station number	Arithmetic average, tons/mi^2/mo		Maximum, tons/mi^2-mo		Manganese, %		Metals					
								Lead, %		Iron, %		Copper, %	
		1964-65	1950-51	1964-65	1950-51	1964-65	1950-51	1964-65	1950-51	1964-65	1950-51	1964-65	1950-51
Smithers	5	88.9	82.2	121.1	114.6	0.62	0.13	0.036	2.0	0.40	0.63	2.2	0.02
Montgomery	6	55.2	107.5	76.1	152.9	0.14	0.11	0.030	2.0	7.8	0.75	3.6	0.02
Cedar Grove	7	38.1	57.4	117.1	76.5	0.01	-	0.036	-	0.23	-	0.09	-
Marmet	11	29.9	86.5	47.8	105.8	0.01	0.04	0.036	2.0	0.68	0.63	0.14	0.01
Kanawha City	13	22.3	70.8	36.5	92.5	0.01	0.04	0.036	2.0	0.52	0.50	0.17	0.02
North Charleston		68.1	102.3	119.7	153.6	0.01	-	0.036	-	0.43	-	0.11	-
South Charleston		92.1	146.6	146.7	325.0	0.01	-	0.036	-	0.32	-	0.10	-
St. Albans	24	23.9	34.5	45.2	47.1	0.01	0.04	0.036	2.0	0.24	0.38	0.39	0.02
Nitro	25	26.7	27.7	138.2	43.8	0.01	0.09	0.036	2.0	0.14	0.38	0.04	0.001

from Research Appliance Company, which in turn was standardized to the British Standard Batch Type A.[26]

Results - A summary of the sulfation results for the Kanawha Valley for the period of October 1964 through December 1965 is reported in Table 4-24. The highest geometric mean was reported at North Charleston, West (1.1 mg SO_3/100 cm^2-day) and the station with the lowest reported geometric mean was Crede (0.23 mg SO_3/100 cm^2-day). Three of the four stations with the highest reported results, North

Table 4-24. KANAWHA VALLEY SULFATION DATA, OCTOBER 1964 THROUGH DECEMBER 1965 (mg SO_3/100 cm^2-day)

Station location	Station number	Arithmetic mean	Geometric mean	Maximum value	Minimum value
Falls View	1	0.36	0.27	0.96	0.10
Montgomery Heights	2	0.34	0.29	0.87	0.12
Kimberly	3	0.30	0.18	1.37	0.03
Boomer	4	0.44	0.38	1.13	0.20
Smithers	5	0.31	0.29	0.47	0.17
Montgomery	6	0.42	0.31	1.62	0.04
Cedar Grove	7	0.44	0.38	0.96	0.09
Chelyan	8	0.66	0.47	2.20	0.05
Chesapeake	9	0.49	0.40	0.75	0.05
Belle	10	0.57	0.53	0.82	0.19
Marmet	11	0.50	0.45	0.98	0.18
South Malden	12	0.67	0.62	1.09	0.27
Kanawha City	13	0.67	0.59	1.51	0.11
East Charleston	14	0.55	0.52	0.88	0.27
Charleston	15	0.71	0.60	1.29	0.31
Crede	16	0.25	0.23	0.90	0.04
West Charleston	17	0.62	0.56	1.30	0.28
North Charleston, E.	16	0.96	0.75	2.43	0.12
North Charleston, W.	19	1.65	1.13	7.54	0.56
South Charleston, E.	20	1.02	0.96	1.74	0.57
South Charleston, W.	21	0.31	0.29	0.57	0.15
Dunbar	22	0.39	0.39	0.71	0.08
Institute	23	0.56	0.54	0.92	0.38
St. Albans	24	0.46	0.43	0.82	0.24
Nitro	25	0.67	0.45	1.35	0.30
West of St. Albans	26	0.38	0.32	0.94	0.01
West of Nitro	27	0.86	0.82	1.35	0.43

Charleston West, South Charleston East, and North Charleston East, are located near the South Charleston industrial complex. The third highest results were reported from the West of Nitro station, which is located near the Nitro industrial complex. Approximately 33.6 percent of the sulfur oxides are emitted in the South Charleston area, while the emissions reported in the Nitro area are less than those reported for the Cabin Creek, Glasgow, Belle, and Institute areas (see Section III- Emission Inventory).

The South Charleston and Nitro areas both reported significant emissions of sulfuric acid mists, while these types of emissions are reported to be very small in the other areas. Apparently, the rate of sulfation of sulfuric acid mist is greater than that of sulfur oxides. Table 4-25 supports this concept and also indicates that there seems to be little correlation between the sulfation rate results and the amount of sulfates reported in the suspended particulate matter. The sulfation rates reported for the Kanawha City, South Malden, and Charleston stations are comparatively high with no nearby sources, indicating the transport

Table 4-25. COMPARISON OF SULFATION RATES WITH SULFATES AND TOTAL SUSPENDED PARTICULATE MATTER

Station location	Station number	Suspended particulates ($\mu g/m^3$)		Sulfation
		Sulfates	Geometric mean[a]	(mg SO_3/100 cm^2-day)
Falls View	1	13.1[b]	141	0.27
Smithers	5	22.3[c]	290	0.29
Montgomery	6	23.6[b]	332	0.31
Cedar Grove	7	19.6[c]	186	0.38
Marmet	11	17.8[b]	187	0.45
Kanawha City	13	30.1[c]	227	0.59
Charleston	15	22.8[b]	160	0.60
West Charleston	17	32.8[b]	181	0.56
North Charleston	7	22.7[b]	204	1.13
South Charleston	7	25.1[c]	253	0.96
Dunbar	22	19.4[b]	159	0.39
St. Albans	24	18.4[c]	165	0.43
Nitro	25	17.9[c]	141	0.45
West of Nitro	27	15.7[b]	110	0.82

[a] Study results through December 1965.

[b] Results from 1965 winter quarter.

[c] Average of four quarters of sulfate results.

of sulfur oxides from one source area to another. The largest monthly sulfation rate measurements were 7.54 mg SO_3/100 cm^2-day at the North Charleston West station, with the smallest monthly reported values of 0.01 mg SO_3/100 cm^2-day recorded at the West of St. Albans station. Values below 0.1 mg SO_3/100 cm^2-day are of the order of magnitude of the reagent blank and consequently indicate very low sulfation rates.

A comparison of the study sulfation rate results with the proposed St. Louis Metropolitan Area maximum air quality goals (limits), Table 4-26, indicates that 25 of the 27 stations exceeded the goal of a yearly geometric mean of 0.25 mg SO_3/100 cm^2-day and 26 of the 27 sampling sites exceeded the monthly goal of 0.50 mg SO_3/100 cm^2-day. Only the Crede and Kimberly stations were under the St. Louis yearly goal and only the Smithers station was under the monthly goal. This comparison indicates that a valley-wide reduction of sulfur oxide emissions would be required to reduce concentrations to meet the proposed St. Louis air quality limits.

Table 4-26. SULFATION RATE AMBIENT AIR QUALITY GOALS IN THE UNITED STATES, 1966

St. Louis[10] (Metropolitan Area)

Maximum permissible concentration 0.25 mg SO_3/100 cm^2-day, annual average.

0.50 mg SO_3/100 cm^2-day, for any 1-month period.

A compilation of the maximum, monthly and seasonal averages of the Kanawha Valley area sulfation rates, Figure 4-8, indicates significant seasonal variations in these values. Data obtained for a period of less than two years are not sufficient to determine monthly and seasonal patterns with any degree of certainty.

Mobile Laboratory

Outdoor air concentrations of sulfur dioxide, nitrogen dioxide, carbon monoxide, oxidants (as ozone), hydrocarbons, and either suspended particulate (as soiling index) or hydrogen sulfide were continuously measured at seven sites by instruments in the U.S. Public Health Service mobile laboratory. Wind speed and direction were also obtained in order to correlate outdoor air concentrations with meteorological measurements and calculations.

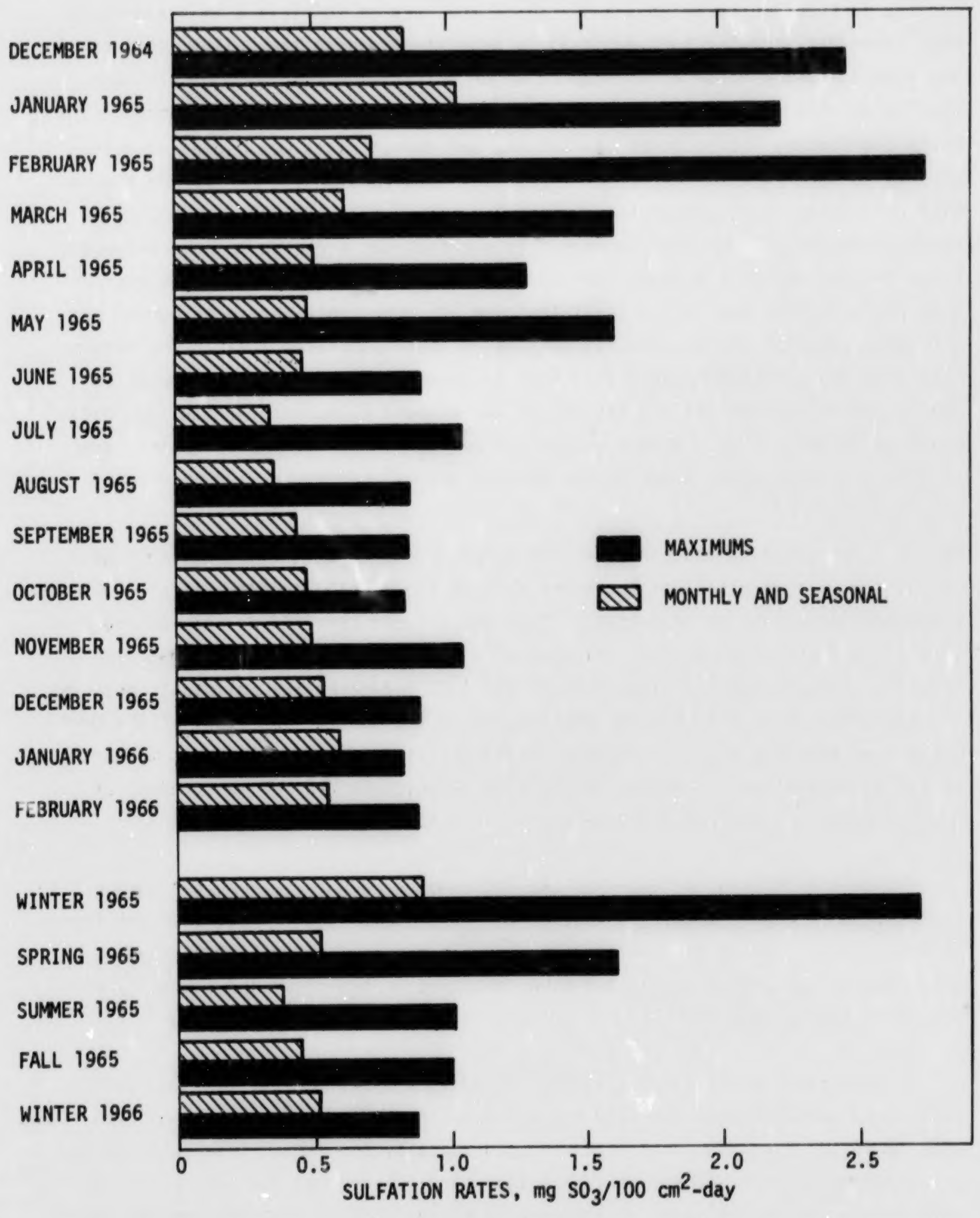


Figure 4-8. Kanawha Valley sulfation rates, maximums, monthly and seasonal averages.

Sampling Sites - The project agreement contracted for the mobile laboratory to be located in heavily populated areas. Since the lack of sufficient time and equipment prevented sampling in every heavily populated area in the valley, the decision was made to sample those areas with known or potential problems. The downtown Charleston site was selected as the area with the maximum vehicle emissions. The South Charleston, Nitro, North Charleston, and Marmet sites were selected principally to determine the effect of industrial emissions on the air of areas normally considered to be commercial and residential, but having the possibility of being affected by industrial sources. This effect was expected to be pronounced, since natural gas is the major (95+ percent) fuel used in commercial and residential space heating and only a small fraction of combustible refuse is burned on site by commercial and residential sources in these populated areas. The Kanawha City site was selected because this area is commercial and residential with no nearby industrial sources and has one of the highest suspended particulate levels measured in the valley. Also a comparison was to be made of the pollutant levels in this area with other areas in the Kanawha Valley.

Method - The sampling was conducted for 1-month periods during the several seasons of the year at different locations so that "seasonal" variation in air pollution concentrations might be determined. This mobile unit remained at some of the sampling sites for 2-month periods for special studies. Figure 4-9 indicates the location of each sampling site, while Table 4-27 indicates the pollutants measured at each site. Figure 4-9A shows photographs of the mobile laboratory at the North Charleston sampling site. Instrument difficulties prevented continuous measuring of all pollutants at all sites. Especially troublesome was the measurement of hydrocarbons; two instruments were used with little success.

Table 4-28 briefly describes the instruments used to measure the common pollutants. More detailed descriptions of the instruments and methods used are found in Appendix D. Use of the mobile laboratory in previous air pollution studies elsewhere in the United States had been described in technical and community air pollution survey reports.[27-32]

Pollutant concentrations (indicated as a continuous trace on strip-chart recorders) were averaged manually for 1/2-hour intervals and tabulated on data forms. Wind speed and direction data were averaged manually for 1-hour intervals and tabulated on data forms. These data were then card-punched and fed into a computer for data processing and storage. Computer output consisted of finished summary tables on hourly variation in pollutant concentration, daily average and average for a given sampling interval, frequency distribution of hourly average concentrations;

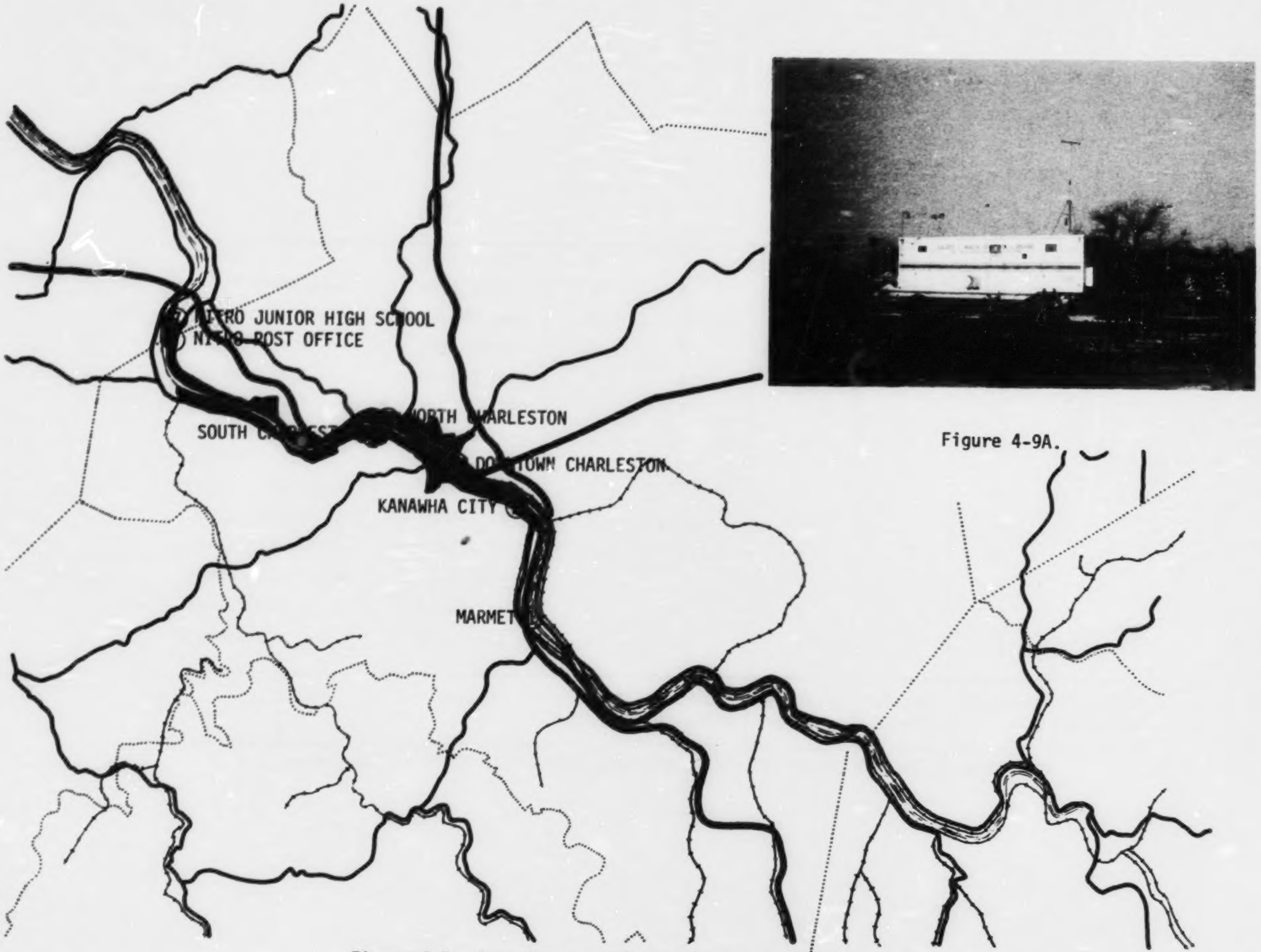

NITRO JUNIOR HIGH SCHOOL
NITRO POST OFFICE
SOUTH CHARLESTON
NORTH CHARLESTON
DOWNTOWN CHARLESTON
KANAWHA CITY
MARMET

Figure 4-9. Location of mobile laboratory sampling sites.

Figure 4-9A.

Table 4-27. GASEOUS POLLUTANTS MEASURED USING CONTINUOUS MONITORING INSTRUMENTS

Station	Season	Sulfur dioxide	Nitrogen dioxide	Carbon monoxide	Carbon dioxide	Oxidants	Hydrogen sulfide
Charleston	Fall 1964	X	X	X		X	
Charleston	Winter 1965	X	X	X			
South Charleston	Fall 1964	X	X	X		X	
South Charleston	Winter 1965	X	X	X	X	X	
South Charleston	Summer 1965	X	X	X		X	
Nitro (Post Office)	Fall 1964	X	X	X		X	
Nitro (Junior high school)	Spring 1965	X	X	X	X	X	X
Kanawha City	Winter 1965	X	X			X	
Kanawha City	Spring 1965	X	X	X	X	X	
Kanawha City	Fall 1965	X	X			X	
North Charleston	Spring 1965	X	X	X	X	X	
North Charleston	Fall 1965	X	X	X	X	X	X
Marmet	Winter 1965	X		X		X	X

Table 4-28. CONTINUOUS AIR MONITORING INSTRUMENTS USED IN THE MOBILE AIR SAMPLING LABORATORY FOR THE DETERMINATION OF GASEOUS POLLUTANTS[a]

Pollutant	Principle of detection and make of instrument	Absorbent	Range,[b] ppm	Sensitivity, ppm	Interference, known
Sulfur dioxide	Conductivity (Davis)	Deionized water	0.01-1.5	0.01	Substances forming ions in aqueous solution such as acids, bases, salts
Oxidants	Coulometric (Mast)	KI - KBr reagent	0.01-1.0	0.01	Oxidizing agents such as NO_2 and Cl_2
Nitrogen dioxide	Photometric (Beckman)	Saltzman reagent	0.01-1.0	0.01	SO_2 at concentrations above 1 ppm, alkyl nitrites
Carbon monoxide	Nondispersive IR absorption (Beckman)	None	1-60	1	None at concentrations usually found in outside ambient air
Carbon dioxide	Nondispersive IR absorption (Beckman)	None	10-600	5	None at concentrations usually found in outside ambient air
Hydrogen sulfide	Photometric (Research Appliance)	Lead-acetate impregnated filter paper	0.001-0.1	0.001	Mercaptans, oxidants, sunlight

[a] Commercially available. Mention of commercial instrumentation does not constitute endorsement by the Public Health Service.

[b] For the air/reagent flow rates or electronic amplification used.

relationship between wind direction and pollutant concentration; relationship between wind speed and pollution concentrations; and between wind speed and wind direction.

Discussion of Results

The significance of the atmospheric pollutant concentrations measured is interpreted in light of existing or proposed ambient air quality goals. Relationships among pollutant concentrations, meteorology, and emission rates are discussed.

Sulfur Dioxide Measurements

Method - The sulfur dioxide electroconductivity analyzer used was calibrated dynamically at regular intervals using SO_2 air mixtures standardized by means of the modified West-Gaeke procedure.[33] To minimize the interference of soluble solids, an in-line particulate filter was used upstream of the air-liquid scrubbing system in the analyzers. Sulfur dioxide concentrations, determined manually by a spectrophotometric method (West-Gaeke), were occasionally compared to values obtained with the continuous electroconductivity analyzer. Generally, good agreement was obtained.

Results - The SO_2 measurements obtained were presented in a form conducive to interpretation of the magnitude of the problem in terms of existing or proposed air quality criteria, Tables 4-29 and 30. These air quality goals are presented in Table 4-31.

The taste threshold of SO_2 (0.3 ppm) was exceeded on one occasion in the Charleston area. Sulfur dioxide concentrations in South Charleston, North Charleston, and Nitro (Junior High School) exceeded the St. Louis, Colorado, and New York State (for certain regions) criteria of 0.1 ppm based on a 24-hour averaging time. New York State criteria of 0.15 ppm for 24 hours was exceeded in South Charleston during the winter sampling period. The St. Louis criteria of 0.20 ppm was exceeded in South Charleston and North Charleston; Nitro (Junior High School), and Marmet. From these comparisons against existing or proposed air quality criteria, air pollution due to SO_2 is definitely a problem in some areas of the Kanawha Valley.

The frequency of occurrence of certain SO_2 concentrations can be obtained by reference to the graphs on cumulative frequency distribution, Figures 4-10, -11, -12, -13, and -14. For example, for North Charleston (Figure 4-14) 1 percent of the time SO_2 concentrations were greater than 0.20 ppm in the fall and greater than 0.31 ppm in the spring. Concentrations which are exceeded 1, 10, 50, and 90 percent

Table 4-29. SULFUR DIOXIDE MEASUREMENTS FOR 1-HOUR AVERAGING TIME

Station	Season	Number of measurements	Number of occurrences >0.2 ppm	Number of occurrences >0.25 ppm	Maximum, ppm	Minimum, ppm
Charleston	Fall 1964	921	0	0	0.11	0.02
Charleston	Winter 1965	728	0	0	0.20	0.02
South Charleston	Fall 1964	627	0	0	0.18	0.01
South Charleston	Winter 1965	763	6	1	0.46	0.01
South Charleston	Summer 1965	370	2	1	0.29	0.02
Nitro (Post Office)	Fall 1964	601	0	0	0.26	0.01
Nitro (Junior high school)	Spring 1965	352	3	0	0.41	0.01
Kanawha City	Winter 1965	300	0	0	0.11	0.01
Kanawha City	Summer 1965	467	0	0	0.07	0.01
Kanawha City	Fall 1965	396	0	0	0.12	0.02
North Charleston	Spring 1965	226	7	6	0.34	0.02
North Charleston	Fall 1965	246	10	1	0.37	0.01
Marmet	Winter 1966	877	2	0	0.32	0.01

Table 4-30. SULFUR DIOXIDE MEASUREMENTS FOR 24-HOUR AVERAGING TIME

Station	Season	Number of measurements	Number of occurrences (>0.1 ppm)	Number of occurrences (>0.15 ppm)	Maximum, ppm	Minimum, ppm
Charleston	Fall 1964	43	0	0	0.05	0.02
Charleston	Winter 1965	33	0	0	0.08	0.03
South Charleston	Fall 1964	27	0	0	0.05	0.02
South Charleston	Winter 1965	34	3	2	0.16	0.02
South Charleston	Summer 1965	19	0	0	0.10	0.04
Nitro (Post Office)	Fall 1964	27	0	0	0.06	0.01
Nitro (Junior high school)	Spring 1965	19	3	0	0.15	0.01
Kanawha City	Winter 1965	14	0	0	0.05	0.01
Kanawha City	Summer 1965	21	0	0	0.04	0.01
Kanawha City	Fall 1965	18	0	0	0.06	0.03
North Charleston	Spring 1965	10	2	0	0.12	0.04
North Charleston	Fall 1965	54	1	0	0.14	0.01
Marmet	Winter 1965	37	0	0	0.08	0.01

Table 4-31. AMBIENT AIR STANDARDS OR CRITERIA FOR SULFUR DIOXIDE FOR AREAS IN THE UNITED STATES, 1966

Area	Standard criteria (Not to exceed stated concentration, ppm)
California[34]	0.30, average for 8 hours 1.0, average for 1 hour
Colorado[6]	0.10, 1 percent of time any 3 months, 24-hour average 0.50, 1 percent of time any 3 months, 1-hour average
Dade County, Fla.[35]	0.10
New York State[7] (Vary according to regions)	0.10, 1 percent of time To 0.15, 2 percent of time, 24-hour average
St. Louis[10]	0.02, annual average 0.10, 1 percent of days in any 3 consecutive months, 24-hour average 0.20, once in any 4 consecutive days, 1-hour average
Pennsylvania[9]	0.5, 1-hour average 0.25, 24-hour average 0.05, 30-day average

of the time at each sampling station are presented in Table 4-32. Reference to Figures 4-10 through 4-14 shows that the New York ambient air quality criteria for a certain region not to be exceeded more than 0.25 ppm 1 percent of the time was exceeded in North Charleston and South Charleston. Concentrations greater than 0.11 ppm occurred 10 percent of the time in South Charleston, Nitro (Junior High School), and North Charleston. For the other areas in the Kanawha Valley where measurements were made, the frequency of occurrence of concentrations greater than 0.11 ppm was about an order of magnitude lower. The analysis further suggests that air pollution, due to SO_2, is a problem of greater magnitude in areas of North and South Charleston and Nitro.

The high SO_2 concentrations (greater than 0.2 ppm for 1 hour) obtained in North and South Charleston and Nitro were studied in relation to meteorological conditions in an attempt to relate the occurrence of elevated SO_2 concentration to possible sources of pollution, Tables 4-33, -34, and -35.

Table 4-32. FREQUENCY DISTRIBUTION OF HOURLY SULFUR DIOXIDE CONCENTRATIONS

Station	Season	Percent of time concentration stated (ppm) is exceeded			
		90	50	10	1
Charleston	Fall 1964	0.02	0.03	0.03	0.06
Charleston	Winter 1965	0.04	0.06	0.08	0.13
South Charleston	Fall 1964	0.02	0.02	0.04	0.08
South Charleston	Winter 1965	0.02	0.06	0.12	0.20
South Charleston	Summer 1965	0.03	0.07	0.11	0.25
Nitro (Post Office)	Fall 1964	0.01	0.02	0.04	0.10
Nitro (Junior High School)	Spring 1965	0.01	0.02	0.13	0.22
Kanawha City	Winter 1965	-	0.04	0.06	0.10
Kanawha City	Summer 1965	0.01	0.02	0.04	0.05
Kanawha City	Fall 1965	0.03	0.03	0.06	0.09
North Charleston	Spring 1965	0.03	0.07	0.11	0.31
North Charleston	Fall 1965	0.01	0.03	0.06	0.20
Marmet	Winter 1966	0.01	0.02	0.03	0.09

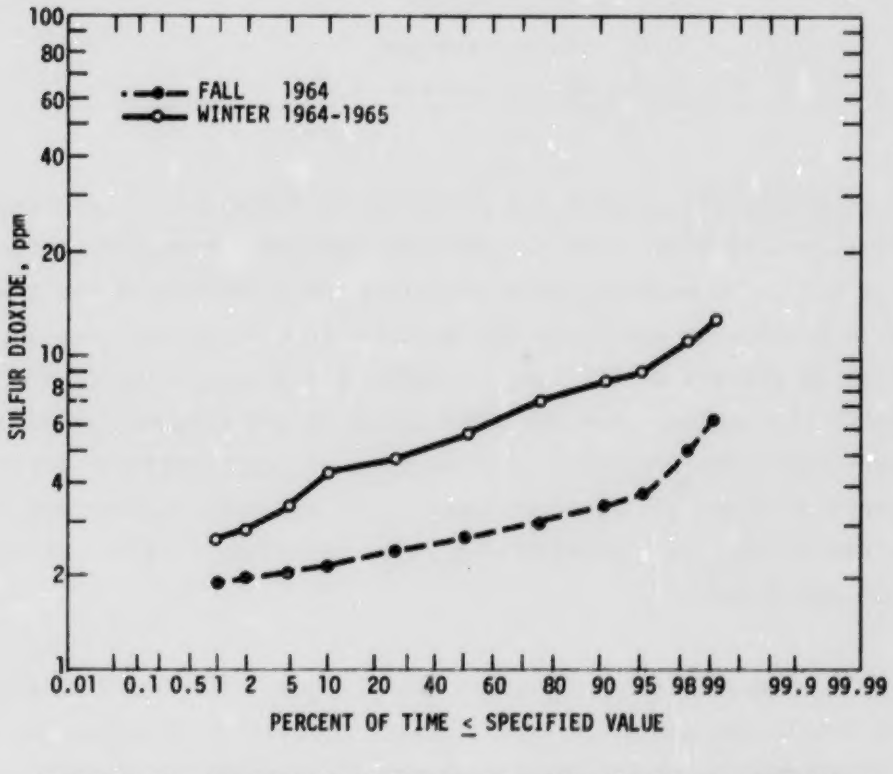


Figure 4-10. Frequency distribution of sulfur dioxide concentrations measured at downtown Charleston.

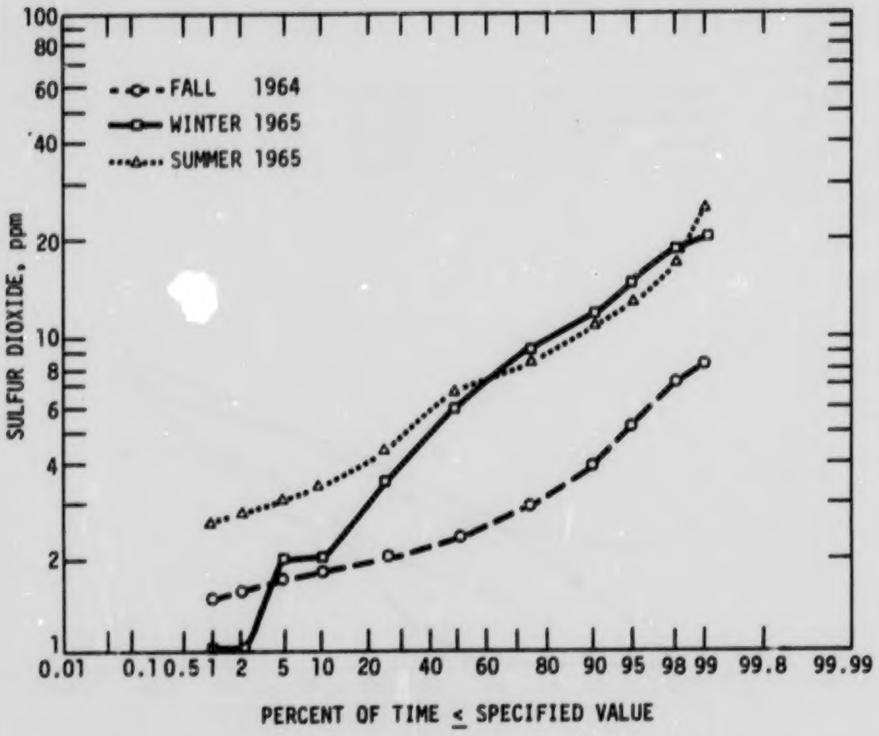


Figure 4-11. Frequency distribution of sulfur dioxide concentrations measured at South Charleston.

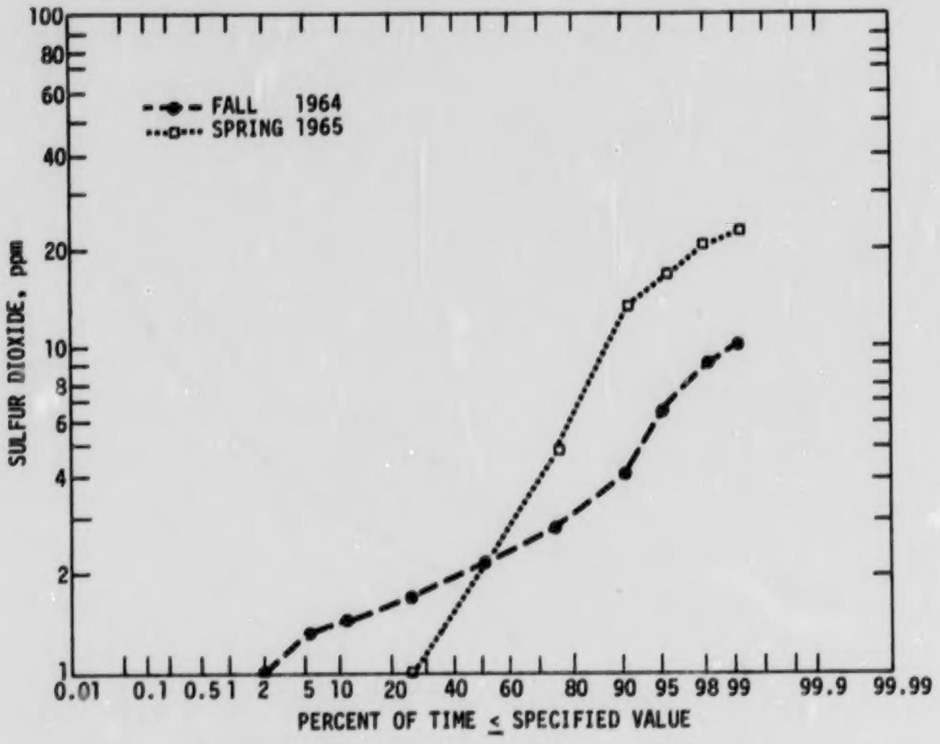


Figure 4-12. Frequency distribution of sulfur dioxide concentrations measured at Nitro.

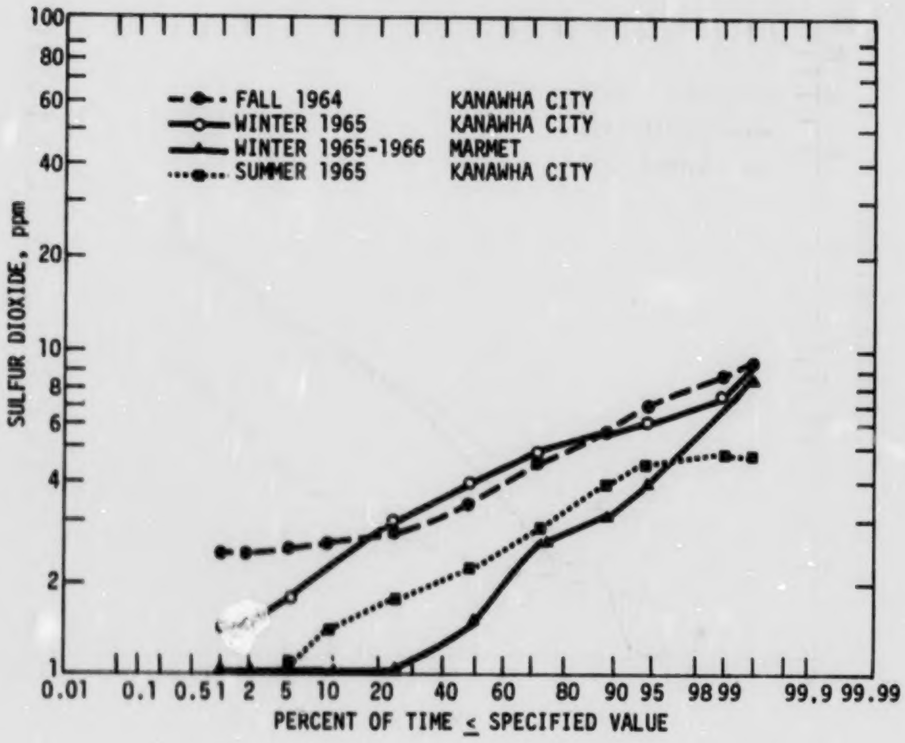


Figure 4-13. Frequency distribution of sulfur dioxide concentrations measured at Kanawha City and Marmet.

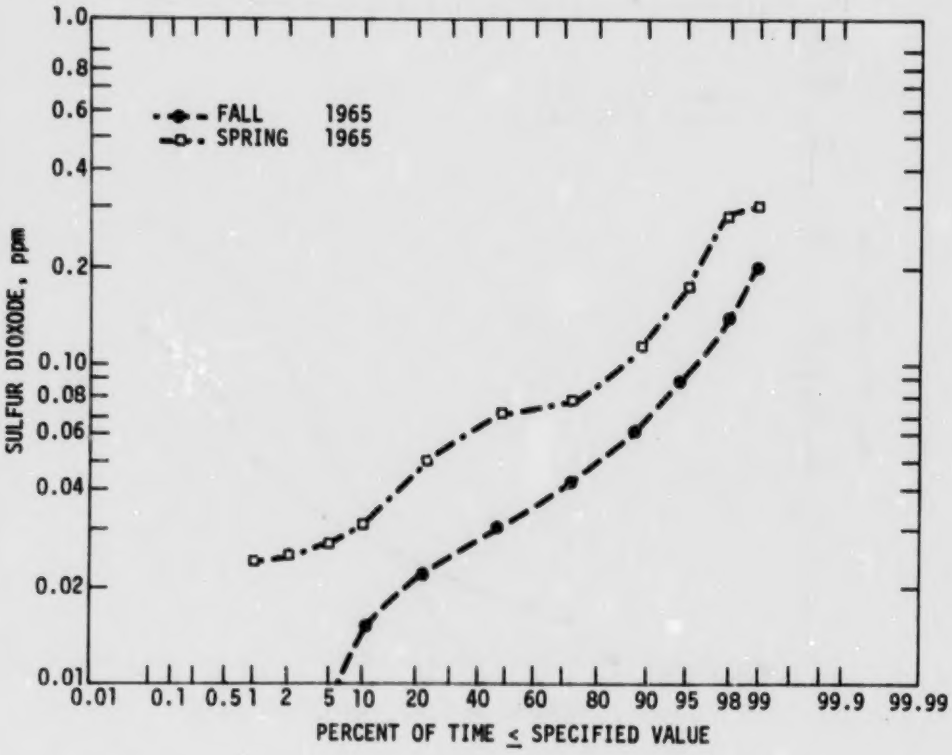


Figure 4-14. Frequency distribution of sulfur dioxide concentrations measured at North Charleston.

The relationship of high SO_2 concentrations in the South Charleston area to wind speed and direction is shown in Table 4-33. In South Charleston, during March of 1965, the occurrence of high SO_2 concentrations was associated with daytime winds from the west and north. Since the South Charleston industrial complex is a major source of SO_2 emissions and is located north to northeast of the sampling site, the high SO_2 concentrations measured may be attributed to direct transport of this contaminant. There is also the possibility of the direct transport of SO_2 from the Institute complex several miles to the west of the sampling site. Because the high SO_2 concentrations measured in South Charleston during the summer sampling period occurred during the evening hours under light wind conditions, the direct transport of pollutants from possible sources to the sampling station is thus demonstrated. Emitted pollutants are trapped within the valley below the inversion level and flow down the valley walls and inward toward the river, under stable meteorological conditions which produce drainage winds. There is also the possibility of pollutants originating in the South Charleston industrial complex to flow out toward the valley walls and be recycled back to the point of origin under inversion conditions because of the "heat island" effect (see Section II, Meteorology).

Table 4-33. RELATIONSHIP OF SULFUR DIOXIDE CONCENTRATIONS GREATER THAN 0.2 PPM TO WIND SPEED AND DIRECTION IN SOUTH CHARLESTON

Sulfur dioxide, ppm	Date, 1965	Time	Wind speed, mph	Wind direction, angular degrees
0.21	2/1	0000	2.0	360
0.21	3/1	1000	2.5	290
0.31	3/8	1200	3.5	290
0.46	3/8	1300	3.0	250
0.23	3/8	1400	4.0	270
0.24	3/8	1500	5.5	340
0.24	3/8	1600	5.0	350
0.25	7/10	1900	2.0	135
0.29	7/10	2000	2.0	N.A.[a]
0.24	7/10	2100	2.0	N.A.
0.29	8/2	2100	1.5	270

[a] N.A. - Not Assignable.

The relationship of average SO_2 concentrations to wind direction in South Charleston is shown in Figures 4-15 and 16. During February and March, the higher pollutant concentrations were measured with wind flows from the northeast and south-

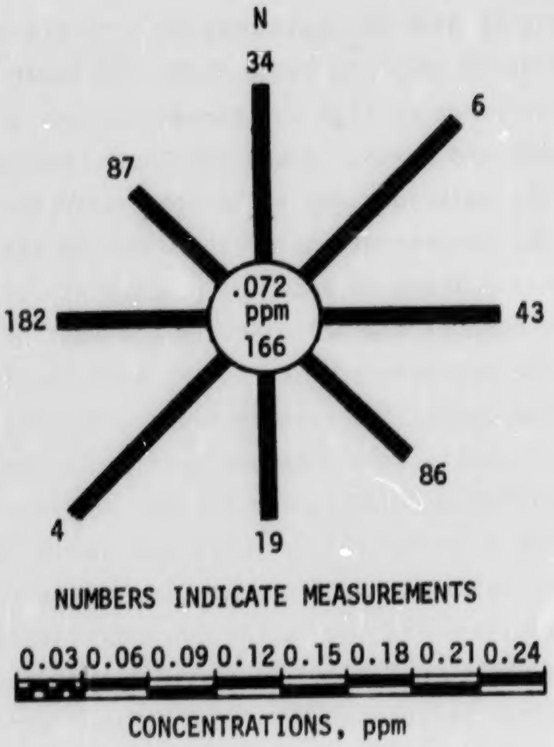


Figure 4-15. Sulfur dioxide pollution rose for South Charleston, February and March of 1965.

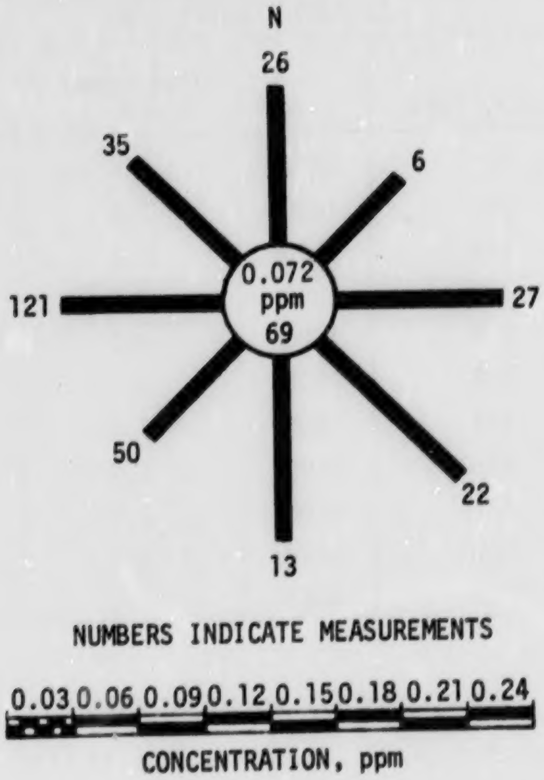


Figure 4-16. Sulfur dioxide pollution rose for South Charleston, July and August 1965.

west. The higher values were recorded with a south-southeast or downriver air flow during July and August of 1968. The number of measurements from these directions was small. (The number of SO_2 concentration measurements obtained for each wind direction is indicated by numbers on the circumference of the outer circle of Figures 4-15 and -16). The relationship between wind speed and average SO_2 concentration during the winter sampling period in South Charleston, Figure 4-17, indicates a decreasing pollution level with increasing wind speeds with one exception; namely, when wind speeds are relatively strong (greater than 12 mph). This relationship indicates the effect of aerodynamic downwash which occurs at high winds. The increase of pollutant concentration during calms indicates the possible recirculation of pollutants to the valley walls and their subsequent return to the industrial complex at ground (low) level.

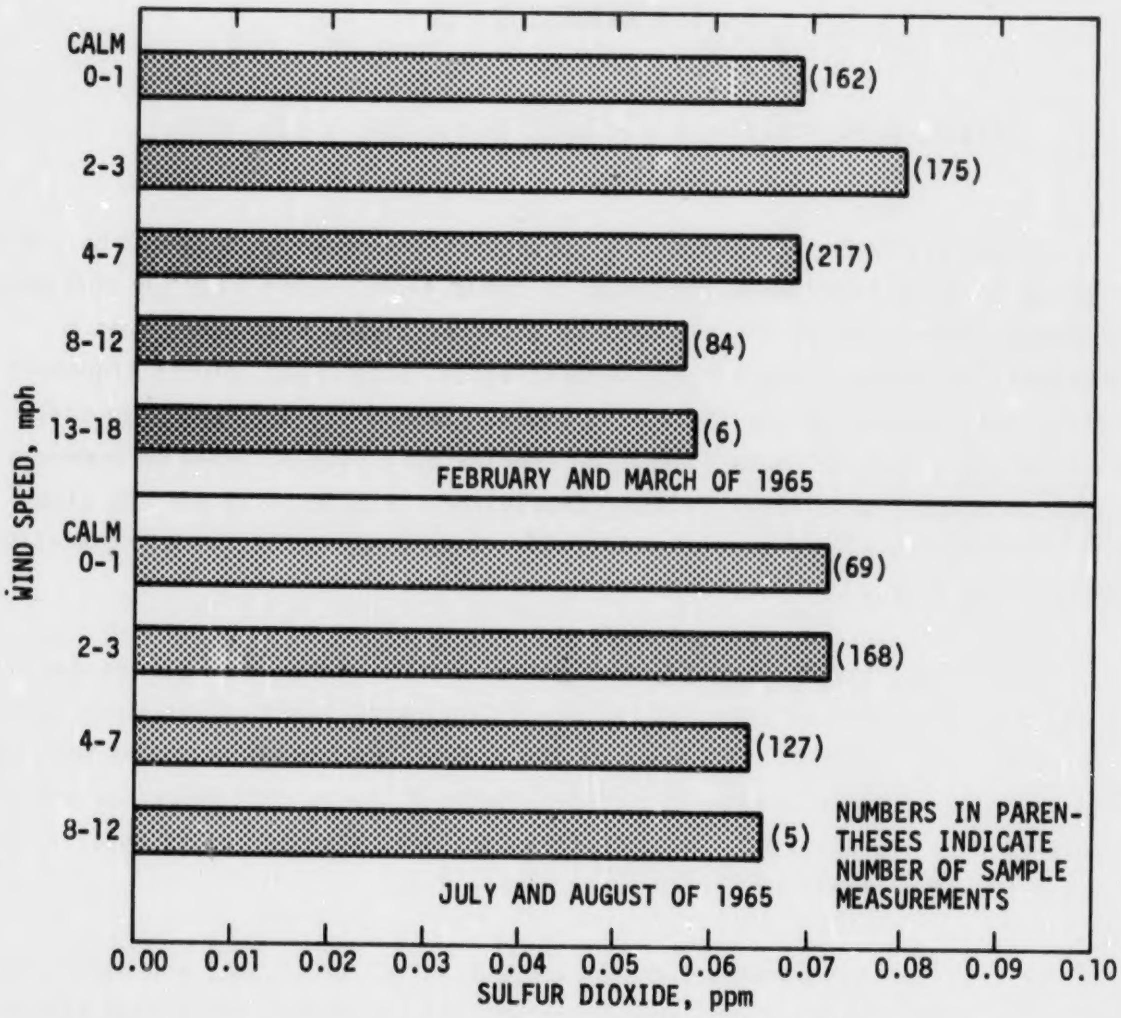


Figure 4-17. Relationship of sulfur dioxide concentrations to wind speed for South Charleston (Station 003).

The wind rose for South Charleston during the winter sampling period, Figure 4-18, shows a more frequent northwesterly wind direction and also the occurrence of higher wind speed from this direction. Average SO_2 concentration was smallest at the wind direction which was associated with the strongest winds.

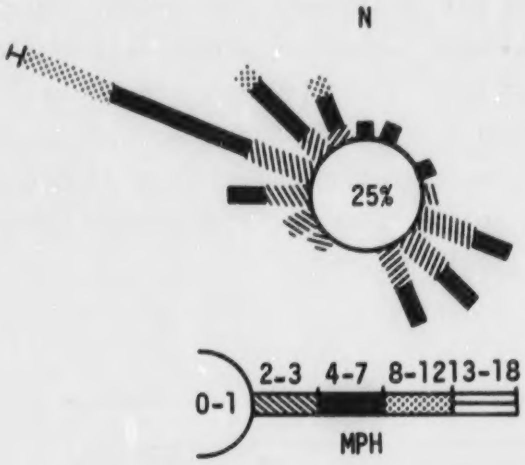


Figure 4-18. Wind rose for South Charleston, winter 1965.

Source relationships between SO_2 concentrations (greater than 0.2 ppm) and meteorology in North Charleston are shown in Table 4-34. These high SO_2 concentrations generally occurred during the daytime with relatively high winds from a southwesterly direction. Under these meteorological conditions, direct transport of pollutants from sources to the station is shown. Smoke, fly ash, and acid mist plumes from stacks in the South Charleston complex have been observed on numerous occasions to reach ground level in North Charleston. Figures 4-19 and -20 also show the same strong wind direction correlation with atmospheric SO_2 concentrations at the sampling site.

Usually, pollution concentrations decrease with higher wind speeds due to the turbulence or mixing effect. At the North Charleston location, as shown by the wind roses (Figures 4-21 and -22), most of the higher wind speeds occurred from the southwest and west, which are the directions that pollutants from major sources would be transported to the station. Thus, in this location, stronger winds usually result in greater SO_2 concentrations, as shown in Figure 4-23.

The relationship between high SO_2 concentrations (>0.2 ppm) and winds that transport pollutants in the Nitro area is shown in Table 4-35. These high concentrations were found due to local conditions during nighttime air drainage when direct transport of pollutant from source to station is unlikely, unless the emission

Table 4-34. RELATIONSHIP OF SULFUR DIOXIDE CONCENTRATIONS GREATER THAN 0.2 PPM TO WIND SPEED AND DIRECTION IN NORTH CHARLESTON

Sulfur dioxide, ppm	Date, 1965	Time	Wind speed, mph	Wind direction, angular degrees
0.26	3/22	0900	11.0	220
0.31		1000	12.5	220
0.34		1100	14.5	230
0.28		1200	14.0	240
0.29	3/23	1100	12.5	220
0.30		1400	12.5	240
0.27		1500	12.0	230
0.33	10/23	0100	6.0	230
0.20	10/30	1100	8.5	250
0.29	10/31	1000	10.0	230
0.21	11/16	0700	5.5	225
0.21		1200	5.0	240
0.24		1500	6.0	235
0.23		1700	7.5	220
0.22		1800	6.5	220
0.37		2100	11.5	225
0.24		2200	13.5	280
0.23	11/20	1700	2.0	000
0.20	12/10	1200	2.0	130
0.20		1300	3.0	135
0.29	3/22	1700	8.5	200

source is near ground level. The wind direction associated with high daytime SO_2 concentrations was west and generally occurred from 9 to 10:00 a.m., possibly from fumigation at the breakup of the morning inversion. This would seem to indicate that the SO_2 emissions are probably from an industrial complex, located either north or upriver of the sampling site.

Generally, the higher average SO_2 concentrations were found when winds were from the south through west to the northwest directions, with relatively low concentrations from the north through southwest as indicated in Figure 4-24. Also, SO_2 concentrations were found to increase slightly as the wind speed increases from calm

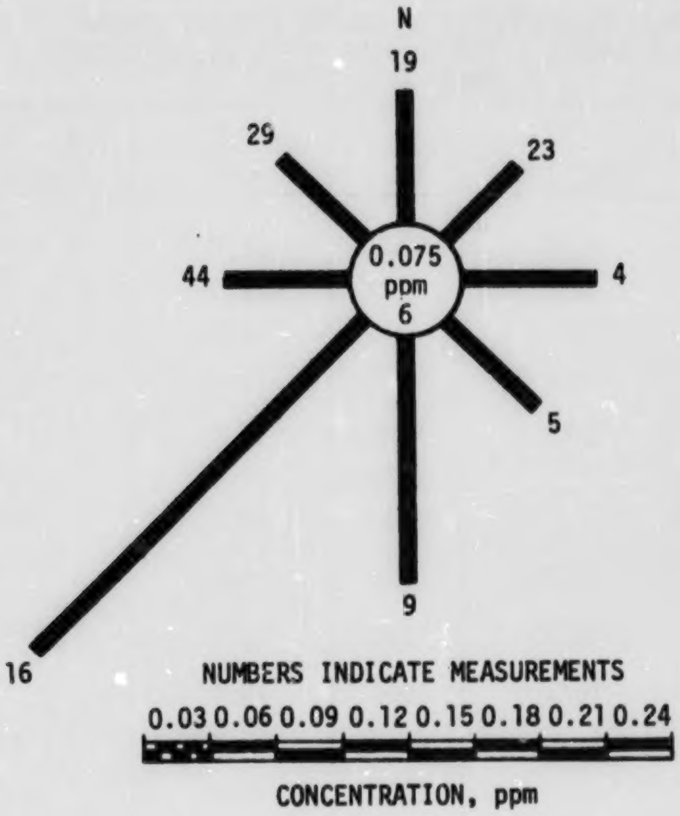


Figure 4-19. Sulfur dioxide pollution rose for North Charleston, March and May 1965.

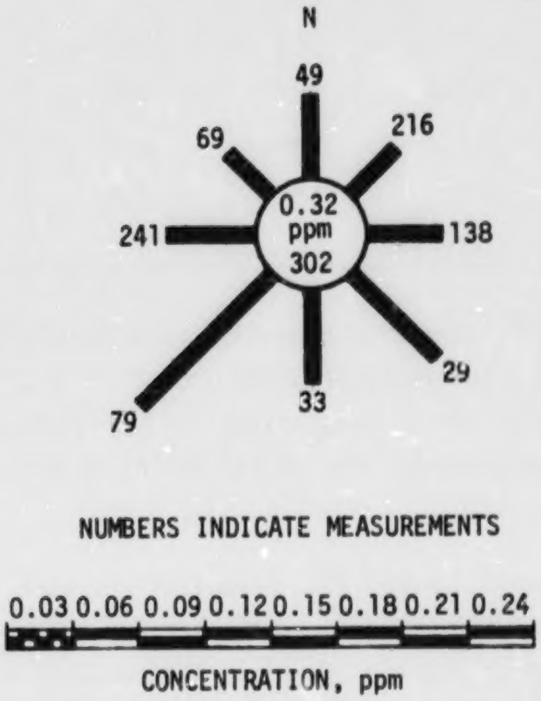


Figure 4-20. Sulfur dioxide pollution rose for North Charleston, November and December 1965.

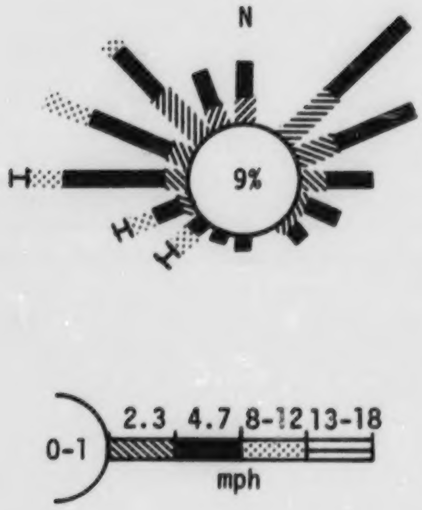


Figure 4-21. Wind rose for North Charleston, spring 1965.

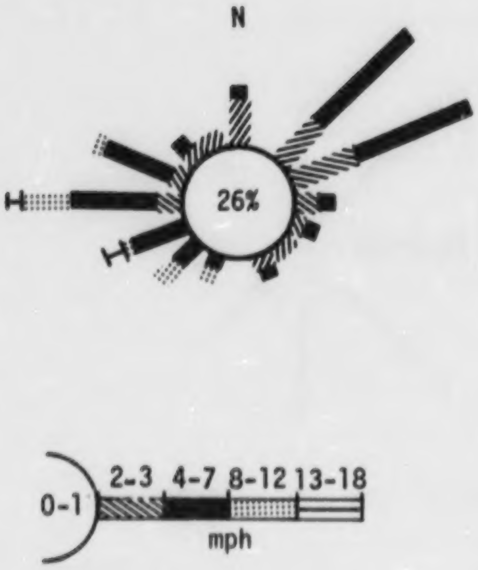


Figure 4-22. Wind rose for North Charleston, fall 1965.

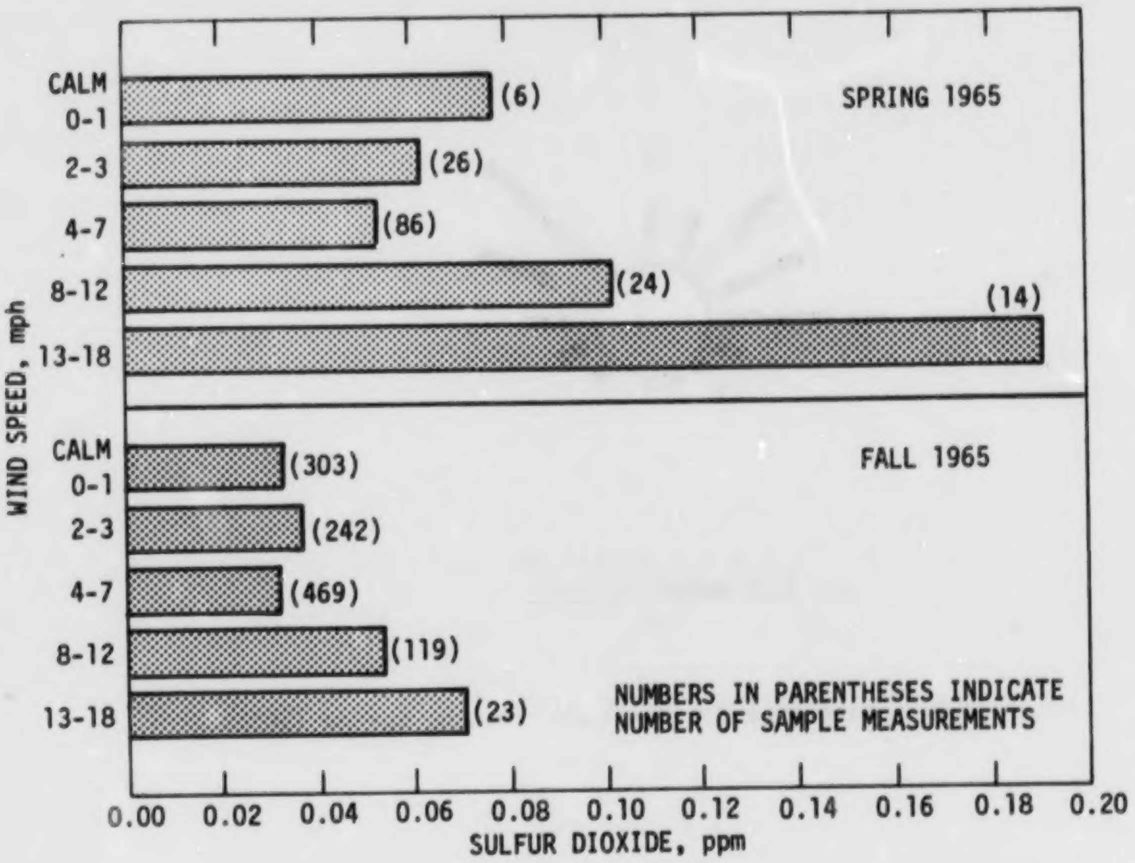


Figure 4-23. Relationship of sulfur dioxide concentrations to wind speed for North Charleston.

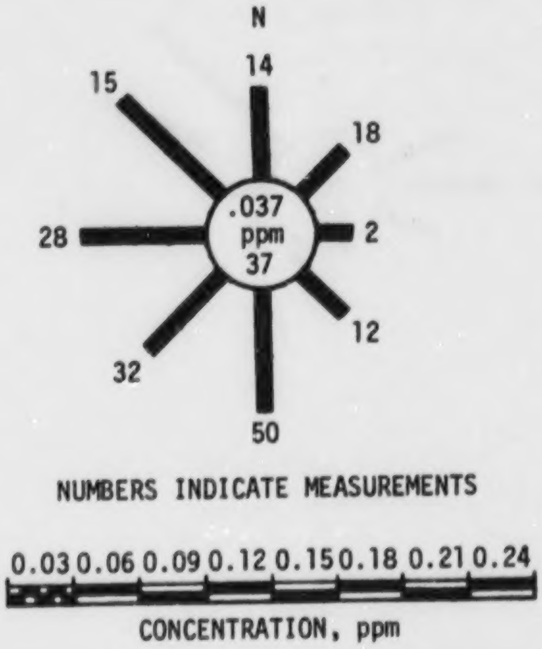


Figure 4-24. Sulfur dioxide pollution rose for Nitro, May and June 1965.

Table 4-35. RELATIONSHIP OF SULFUR DIOXIDE CONCENTRATIONS GREATER THAN 0.2 PPM TO WIND SPEED AND DIRECTION AT NITRO JUNIOR HIGH

Sulfur dioxide, ppm	Date, 1965	Time	Wind speed, mph	Wind direction, angular degrees
0.23	5/24	2000	N.A.[a]	N.A.
0.22	5/26	0200	N.A.	230
0.20		1900	2.0	225
0.22		0200	2.5	180
0.25	5/28	0900	3.0	270
0.41		1000	4.5	270
0.20	5/24	1600	3.0	270
0.20		1900	0.0	

[a] N.A. - Not Assignable.

to 7 mph, but decreased considerably as the wind speed increased above 7 mph, as shown in Figure 4-25. This relationship indicated that sources of SO_2 affecting the nearby sampling site often pass over the sampling site at a higher level when wind speeds are light (<4 mph); that transport of SO_2 to the sampling site is greater at medium wind speeds; and that with high wind speeds, SO_2 emissions are diluted considerably before reaching the sampling site. The wind rose (Figure 4-26) indicates that the highest frequency of wind direction is from the south. This frequency of winds from the south is probably due to nighttime drainage conditions. Southwesterly and westerly winds occur frequently and are also stronger, which is consistent with the most frequent direction of free air aloft as shown in Figure 4-26. The occurrence of relatively high average concentrations of SO_2 with these winds is possibly due to the complex meteorological situation in the Nitro area as described in Section II.

The daily maximum and seasonal sulfur dioxide averages, Table 4-30, and the frequency distribution, Table 4-32, of sulfur dioxide concentrations in the Kanawha Valley were compared with 1964 and 1965 data from CAMP (Continuous Air Monitoring Stations) stations located in seven major metropolitan areas reported in Tables 4-36 and -37. The maximum 24-hour concentration measured in the valley (0.16 ppm at South Charleston, winter of 1965) is lower than the maximum daily SO_2 concentrations measured by CAMP stations with the exception of San Francisco, California (0.08 ppm in 1964); Cincinnati, Ohio (0.15 ppm in 1965); and Denver, Colorado (0.06 ppm in 1965). The maximum daily average concentration for 1964 and 1965 reported by the CAMP stations was 0.68 ppm SO_2 at Chicago, Illinois, and the second highest

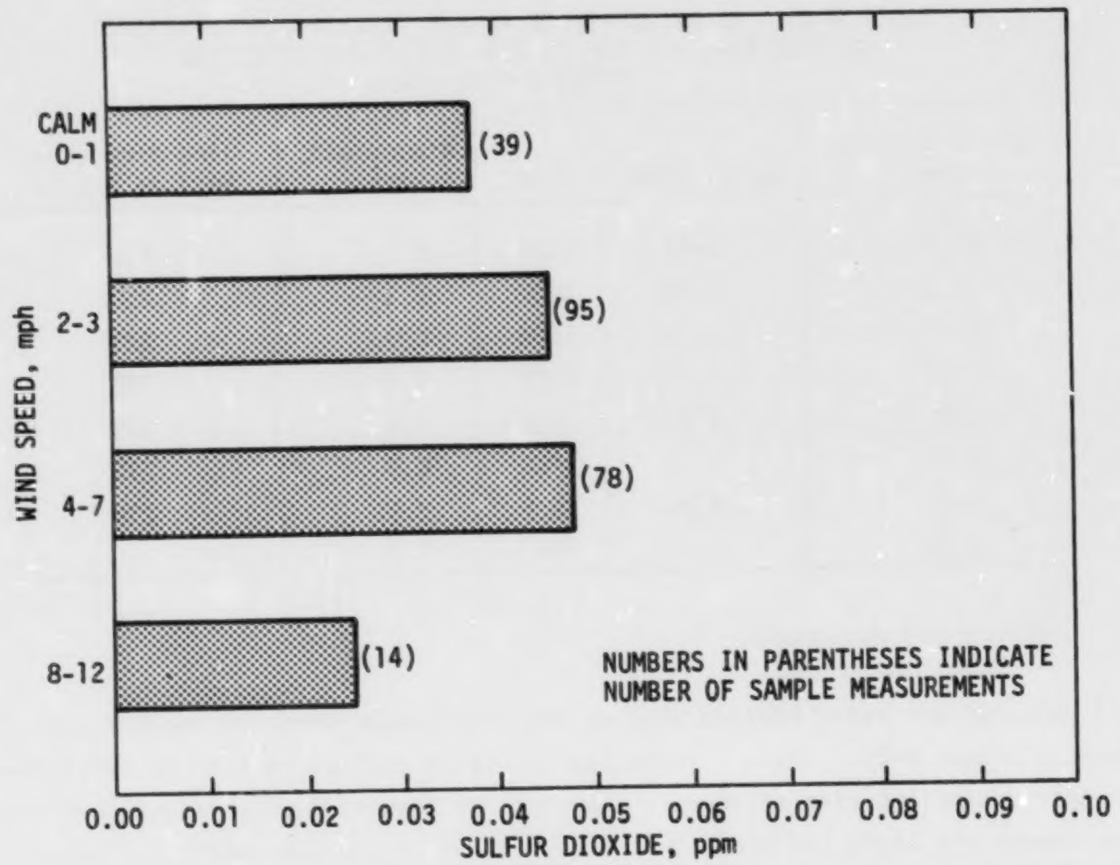


Figure 4-25. Relationship of sulfur dioxide concentrations to wind speed for Nitro, May - June 1965.

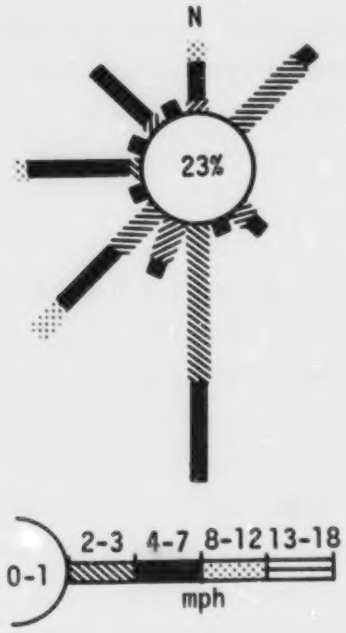


Figure 4-26. Wind rose for Nitro, spring 1965.

value (0.55 ppm) was also reported at Chicago. The study averages (arithmetic) of 0.07 ppm, for South Charleston for the winter and summer of 1965, for North Charleston in the spring of 1965, and for Charleston in the winter of 1964-1965, are comparable to or greater than the maximum monthly averages reported for Washington, D. C. (0.08 ppm in 1965); Cincinnati (0.06 ppm in 1964 and 0.05 ppm in 1965); San Francisco (0.06 ppm in 1964); St. Louis (0.06 ppm in 1965); and Denver (0.03 ppm in 1965). Frequency distribution data on SO_2 (maximum 10 and 1 percent values) for Kanawha Valley cannot readily be compared with the CAMP network because of insufficient data in the study area, although high concentrations in the valley are comparable to those found in St. Louis and Washington, D. C.

Table 4-36. 1964 SULFUR DIOXIDE DATA FROM THE CAMP STATIONS (ppm)

City	Maximum		Yearly average	Percent of time concentration stated is exceeded			
	Daily	Monthly		90	50	10	1
Chicago	0.68	0.34	0.17	0.03	0.13	0.40	0.76
Cincinnati	0.18	0.06	0.04	0.01	0.03	0.07	0.26
Philadelphia	0.43	0.15	0.08	0.00	0.04	0.21	0.47
St. Louis	0.08	0.03	0.02	0.00	0.04	0.14	0.37
San Francisco	0.26	0.09	0.06	0.00	0.01	0.04	0.08
Washington	0.22	0.09	0.05	0.01	0.03	0.10	0.26

Table 4-37. 1965 SULFUR DIOXIDE DATA FROM THE CAMP STATIONS (ppm)

City	Maximum		Yearly average	Percent of time concentration stated is exceeded			
	Daily	Monthly		90	50	10	1
Chicago	0.55	0.27	0.13	0.00	0.07	0.34	0.65
Cincinnati	0.15	0.05	0.03	0.00	0.02	0.07	0.23
Denver	0.06	0.03	0.02	0.00	0.02	0.03	0.09
Philadelphia	0.36	0.13	0.08	0.00	0.06	0.18	0.46
St. Louis	0.19	0.06	0.04	0.00	0.03	0.11	0.29
Washington	0.20	0.08	0.04	0.00	0.04	0.10	0.20

A compilation of SO_2 data obtained during the 1950-1951 Air Pollution Study[17] is presented in Table 4-38. A comparison of these data obtained by the Bureau of Industrial Hygiene, West Virginia Department of Health and the Kettering Laboratory of Cincinnati, and the present study results was made and is shown in Table 4-39. Sulfur dioxide averages for 1951, as measured by the West Virginia Department of Health, are above those found during the 1964-1965 study with the exception of the North Charleston area, where the results are similar. The results reported by the Kettering Laboratory, with the exception of the Marmet-Belle and Nitro areas, are either similar or lower than those reported in the 1964-1965 study. The meteorological conditions were reported as "generally were favorable for the dispersion of the pollutants,"[17] during the sampling by the Kettering Laboratory, whereas a wide range of the various types of meteorological conditions was encountered during the sampling by the West Virginia Department of Health. The maximum values reported by both of these studies are, within experimental error, essentially the same.

Table 4-38. SULFUR DIOXIDE DATA FROM 1950-1951 KANAWHA VALLEY
AIR POLLUTION STUDIES FOR ½-HOUR SAMPLING PERIOD
(ppm)

Station	West Virginia Bureau of Industrial Hygiene[a]				Kettering[b] Laboratory	
	8 a.m. to 4 p.m.		4 p.m. to 10 p.m.			
	Average	Maximum	Average	Maximum	Average	Maximum
Kanawha City	0.10	0.30	0.09	0.28	0.03	0.11
Charleston	0.08	0.37	0.08	0.22	0.02	0.08
South Charleston	0.12	0.59	0.08	0.22	0.01	0.05
					0.04	0.20
North Charleston	0.06	0.16	0.08	0.23	0.03	0.14
					0.03[c]	0.03[c]
St. Albans	0.10	0.69	0.07	0.17	0.01	0.05
Nitro	0.16	0.43			0.12	0.42
					0.00[c]	0.00[c]
Institute	0.14	0.28			0.04	0.07
Belle	0.15	0.38	0.08	0.19	0.06	0.18
Chelyan					0.01	0.03
Glass plants					0.04[d]	0.11[d]
(Kanawha City)					0.02[c]	0.03[c]

[a] For the sampling period of January 15, 1951 to June 11, 1951.

[b] For the sampling period of December 1950, through June 1951.

[c] Upwind from industrial plants.

[d] Downwind from industrial plants.

Table 4-39. COMPARISON OF SULFUR DIOXIDE DATA OBTAINED DURING THE 1950-1951 AND 1964-1965 KANAWHA VALLEY AIR POLLUTION STUDIES (ppm)

Stations	1964-65 Study		1950-51 Studies West Virginia Department of Health				Kettering Laboratory	
			8 a.m. to 4 p.m.		4 p.m. to 10 p.m.			
	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Charleston	0.03	0.11	0.08	0.37	0.08	0.22	0.02	0.08
	0.06	0.34						0.05
South Charleston	0.03	0.22	0.12	0.58	0.08	0.22	0.01[a]	0.05[a]
	0.07	0.46					0.04[b]	0.20[b]
	0.07	0.31						
Nitro (Post Office)	0.03	0.28	0.16	0.42			0.12[c]	0.42[c]
Nitro (Junior high school)	0.04	0.41					0.00[d]	0.00[d]
Kanawha City	0.04	0.13	0.10	0.30	0.08	0.28	0.03	0.11
	0.03	0.08		0.30		0.28	0.04[e]	0.11[e]
	0.04	0.13					0.02[f]	0.03[f]
North Charleston	0.07	0.36	0.06	0.16	0.08	0.22	0.03	0.14[g]
	0.04	0.41					0.03	0.03[h]
Marmet	0.02	0.32	0.15	0.38	0.08	0.19		
Chelyan							0.01	0.02
Institute			0.14	0.28			0.04	0.07
St. Albans			0.10	0.69	0.07	0.17	0.01	0.05

[a] South Charleston, Shephard, and Macon Streets.

[b] Downwind of South Charleston plants.

[c] Nitro, downwind 1 mile from plants.

[d] Nitro, upwind 1 mile from plants.

[e] Kanawha City, downwind of glass plants.

[f] Kanawha City, upwind of glass plants.

[g] North Charleston, Broadway and Third Streets, downwind of plants.

[h] North Charleston, Broadway and Third Streets, upwind of plants.

Carbon Monoxide Measurements

Method - Carbon monoxide was determined by absorption spectroscopy using a continuous, non-dispersive, infrared analyzer. The method is made selective for carbon monoxide by choice of optical filters and by use of carbon monoxide in the detector cell. A filter cell, charged with wet carbon dioxide, is used to minimize the interference of carbon dioxide and water vapor. To prevent the interference of water vapor, the air sample was dried by passage through "Drierite" prior to admittance into the infrared analyzer. The instrument was calibrated daily using pre-purified nitrogen to set the zero response and a standard carbon monoxide-nitrogen gas mixture (about 30 ppm carbon monoxide) to calibrate the upscale response.

Results - Carbon monoxide measurements were examined in reference to the air quality criteria listed in Table 4-40. Data obtained for carbon monoxide are summarized in Table 4-41. Graphs of cumulative frequency distribution of carbon monoxide concentrations are presented in Figures 4-27, -28, -29, -30, and -31. Present standards of California, St. Louis, New York, and Pennsylvania were not exceeded. Hourly concentrations greater than 30 ppm occurred on two occasions, both of them in South Charleston. The greatest 24-hour concentration (16.1 ppm) also occurred in South Charleston. This comparison of measured carbon monoxide concentrations to existing air quality criteria indicates that carbon monoxide is not presently a problem in the Kanawha Valley.

Table 4-40. AMBIENT AIR STANDARDS OR CRITERIA FOR CARBON MONOXIDE FOR AREAS IN THE UNITED STATES, 1966

Area	Standards or criteria, average concentration, ppm
California[34]	30 for 8 hours (serious level) 120 for 1 hour (serious level)
New York[7]	30 ppm for 8 hours 15 for 8 hours, for more than 15 percent of the time 60 for 1 hour, for more than 1 percent of the time
St. Louis[10] (Metropolitan)	30 for 8 hours 120 for 1 hour
Pennsylvania[9]	25 for 24 hours

Table 4-41. SUMMARY AND FREQUENCY DISTRIBUTION OF HOURLY CARBON MONOXIDE CONCENTRATIONS

Station	Season	Number of measurements	Arithmetic mean, ppm	Geometric mean, ppm	Maximum, (1-hour) ppm	Maximum, (24-hour) ppm	Percent of time concentration (ppm) is exceeded		
							50	10	1
Charleston	Fall 1964	688	5.5	4.7	16.5	7.7	5.2	9.5	14.0
Charleston	Winter 1965	185	6.0	4.0	29.3	10.6	5.0	12.0	22.5
South Charleston	Fall 1964	491	6.1	3.6	30.6	16.1	4.4	14.7	26.5
South Charleston	Winter 1965	234	5.2	3.7	13.0	10.3	5.1	10.4	12.7
South Charleston	Summer 1965	475	6.1	5.0	9.9	8.3	6.9	9.4	9.9
Nitro (Post Office)	Fall 1964	233	2.1	1.8	5.2	2.8	2.1	3.7	4.8
Nitro (Junior high school)	Spring 1965	390	3.4	2.7	7.8	4.6	3.1	6.1	7.2
Kanawha City	Summer 1965	196	4.1	4.1	6.4	4.4	4.1	5.5	6.4
North Charleston	Spring 1965	216	4.6	3.0	27.9	8.1	3.4	11.5	27.8
North Charleston	Fall 1965	1,048	6.3	4.9	18.8	11.7	6.0	11.1	15.0
Marmet	Winter 1966	446	3.7	3.3	7.7	5.4	3.7	5.9	7.2

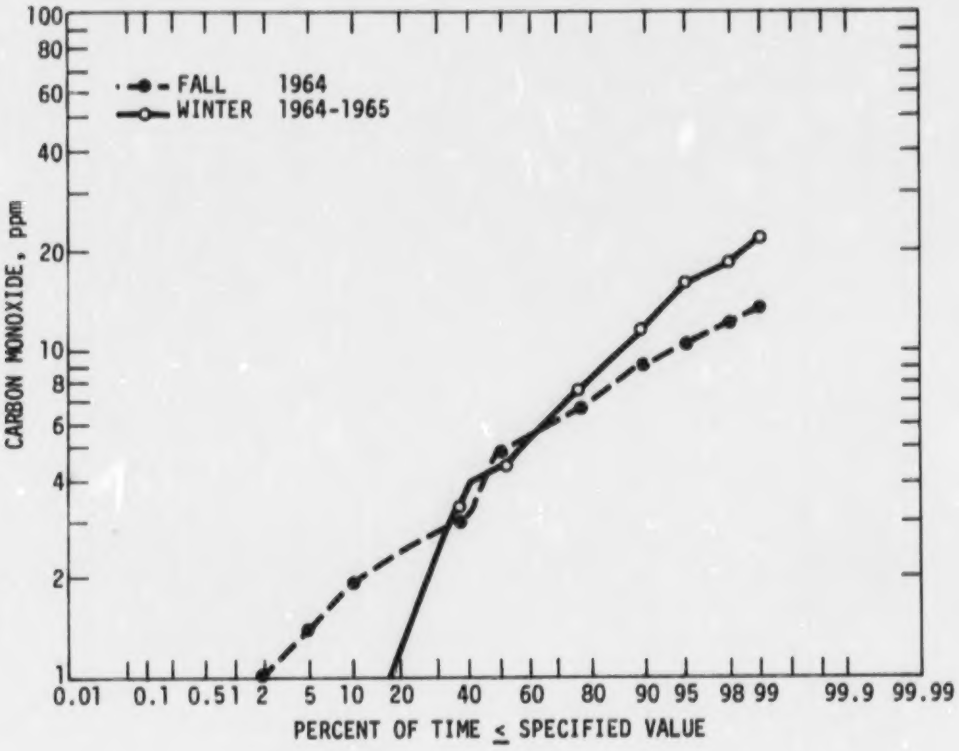


Figure 4-27. Frequency distribution of carbon monoxide measured at downtown Charleston.

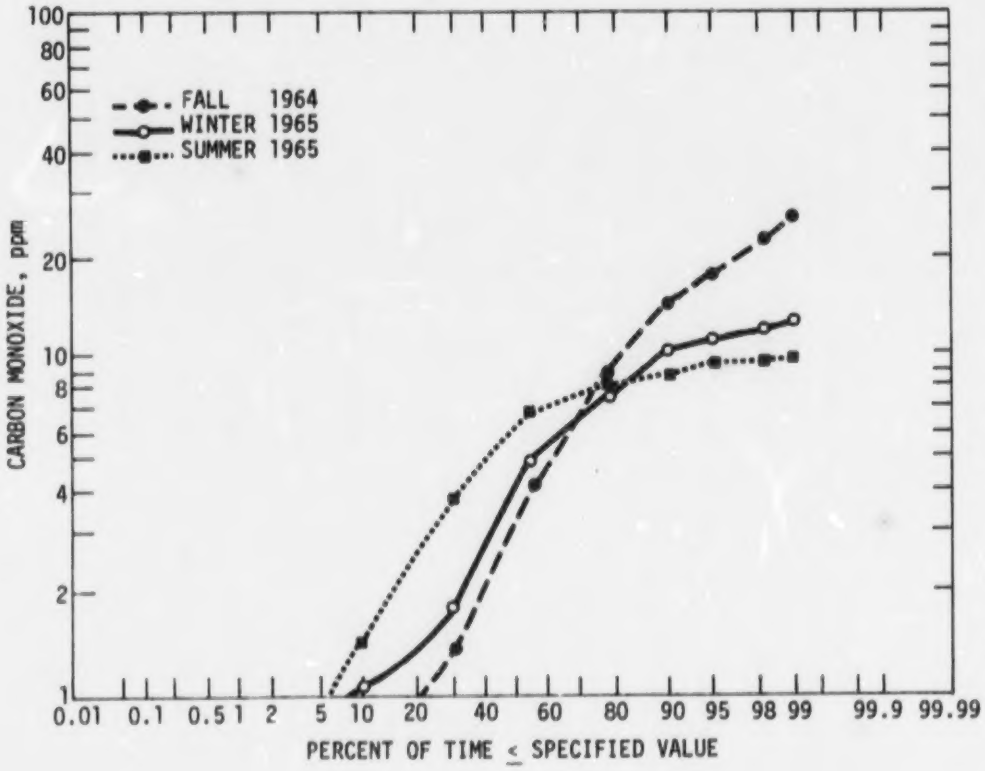


Figure 4-28. Frequency distribution of carbon monoxide measured at South Charleston.

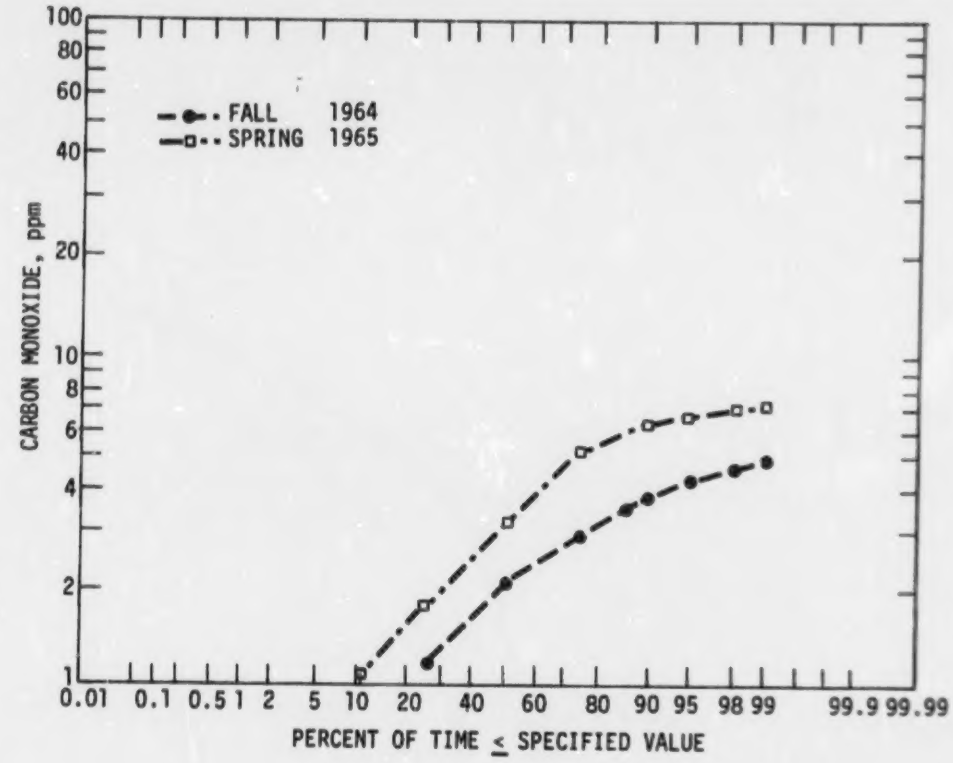


Figure 4-29. Frequency distribution of carbon monoxide measured at Nitro.

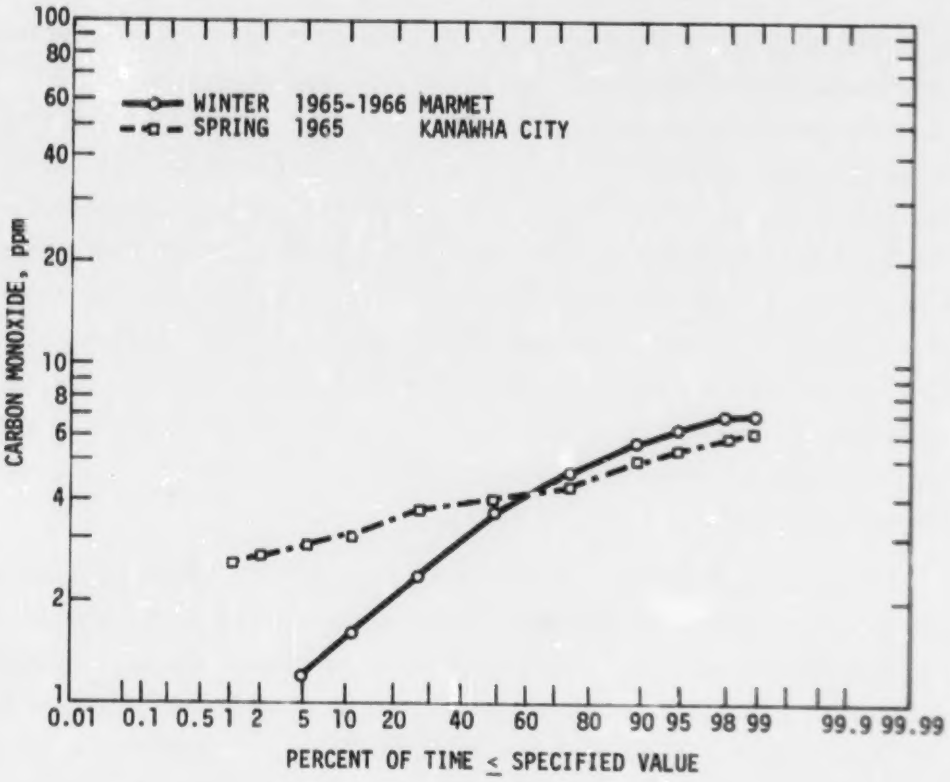


Figure 4-30. Frequency distribution of carbon monoxide measured at Kanawha City and Marmet.

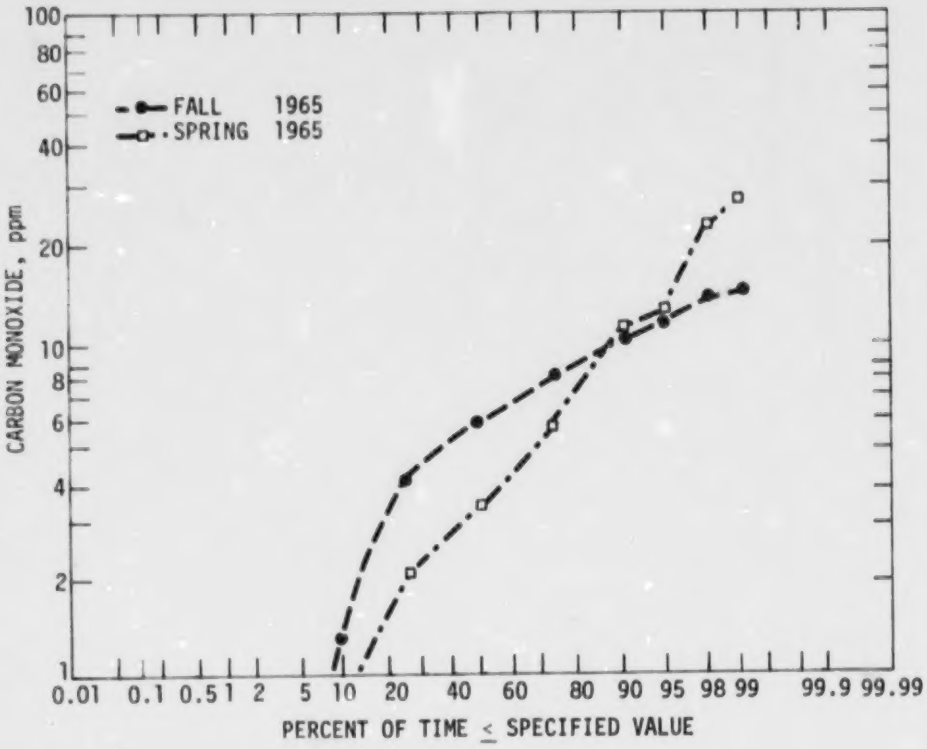


Figure 4-31. Frequency distribution of carbon monoxide measured at North Charleston.

The data in Table 4-41 can also be used to determine relative carbon monoxide pollution conditions in the areas where measurements were made. Carbon monoxide concentrations greater than 22 ppm occurred 1 percent of the time that measurements were obtained in Charleston during the winter, in South Charleston during the fall, and North Charleston during the spring. Concentrations greater than 9 ppm occurred 10 percent of the time in Charleston, South Charleston, and North Charleston in all seasons that measurements were made. Concentrations greater than 9 ppm occurred less than 1 percent of the time in Nitro, Kanawha City, and Marmet. The Charleston areas, including North Charleston and South Charleston, with high carbon monoxide emissions, have the highest reported carbon monoxide concentrations. The measured carbon monoxide concentrations are in general agreement with the estimated emissions.

From the pollution rose shown in Figure 4-32, there appears to be no directionality associated with average carbon monoxide concentrations in Charleston during the summer and fall sampling period, nor would any be expected due to the sampling site being located downtown and surrounded by buildings and due, also, to the random distribution of Kanawha Valley sources of carbon monoxide (mainly automobiles). Average carbon monoxide concentration decreases slightly with increasing wind speed from calm to 12 mph except at 4 to 7 mph where a slight increase in con-

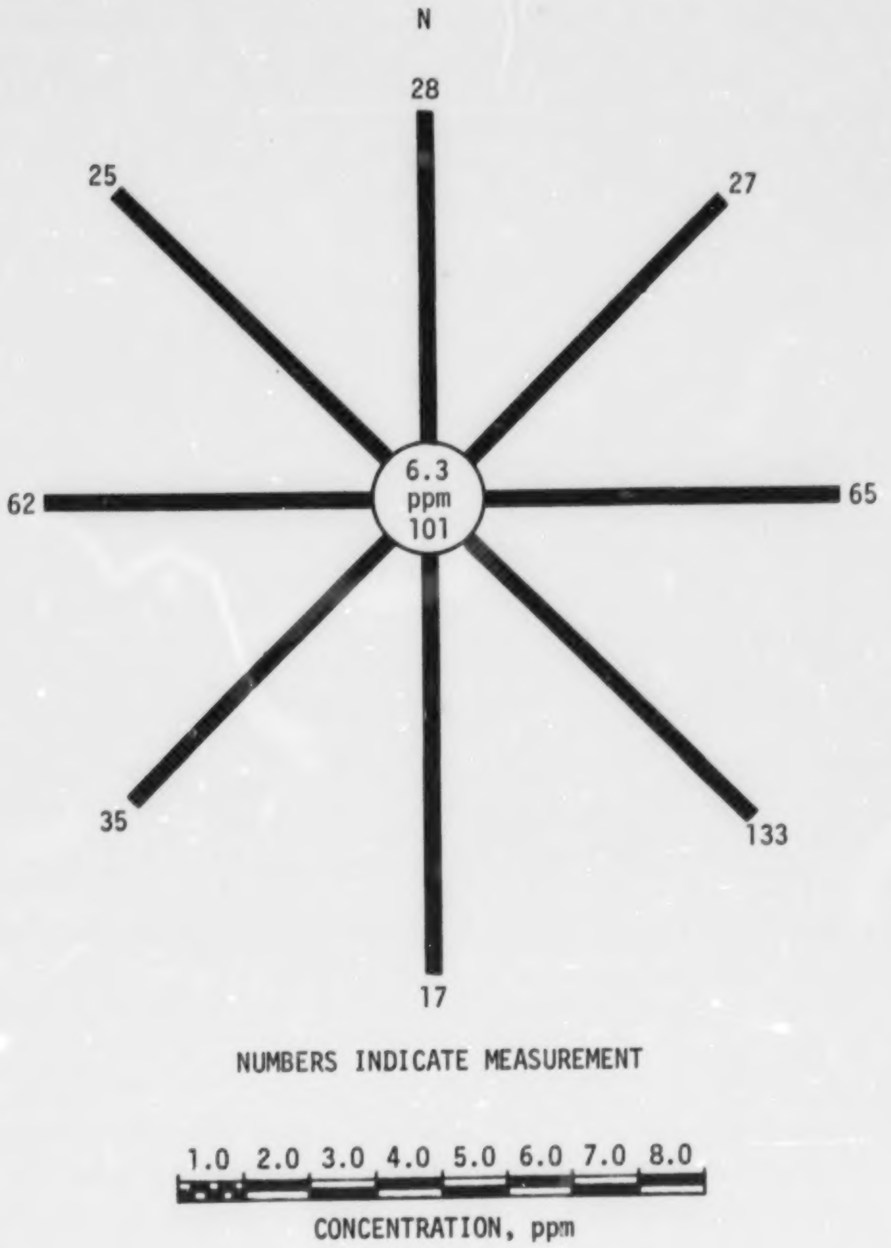


Figure 4-32. Carbon monoxide pollution rose for downtown Charleston, August and September 1964.

centration occurs (see Figure 4-33). This relationship between wind speed and average carbon monoxide concentration suggests that higher wind speeds do not effectively reduce carbon monoxide concentration at this sampling location, possibly because the wind speeds at street level do not increase to the same extent that they do above the Federal Building.

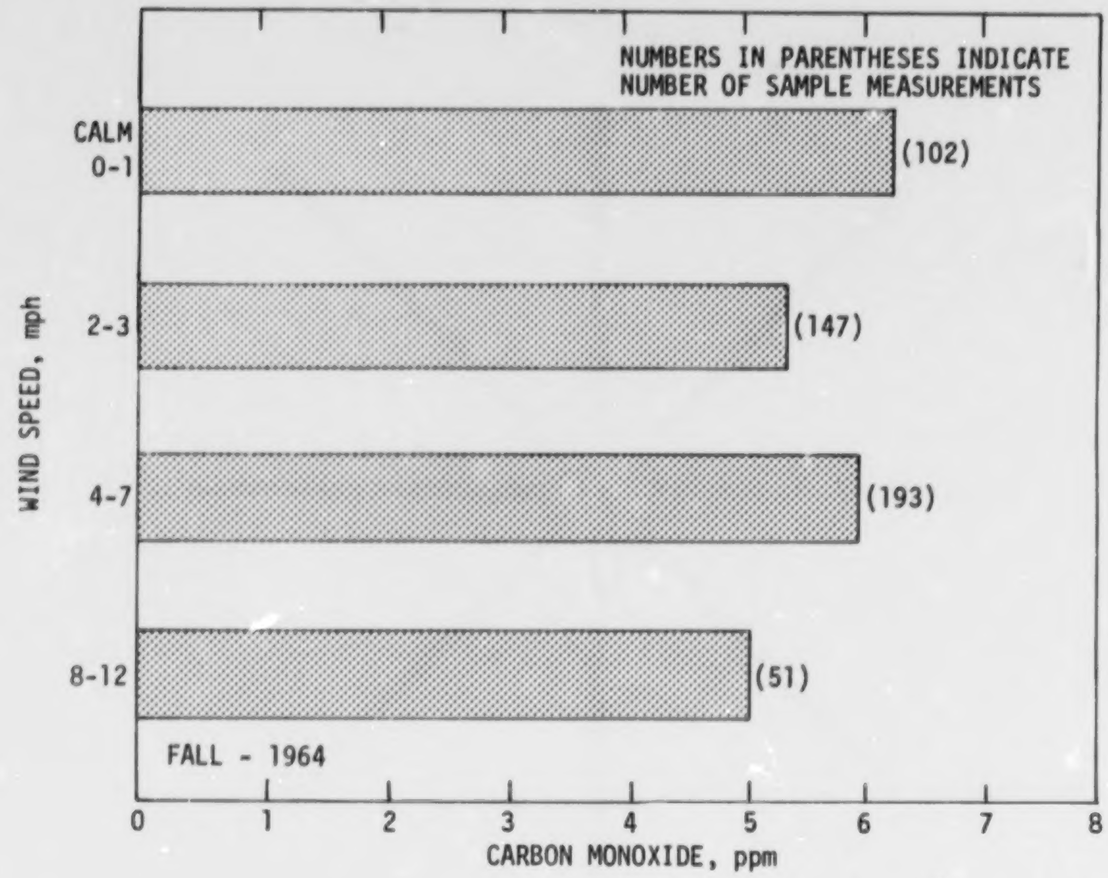


Figure 4-33. Relationship of carbon monoxide concentrations to wind speed for downtown Charleston.

In South Charleston during winter sampling period, the relationship of average carbon monoxide concentrations to wind directions shows that greatest concentrations occur at wind directions of east through south, Figure 4-34. The average wind speed for these wind directions is low. There is little or no variation of average carbon monoxide concentrations with wind direction for all other wind directions. Strongest winds occurred at a northwesterly wind direction which would tend to dilute carbon monoxide concentration reaching the measuring site from downtown South Charleston. In the summer sampling period (Figure 4-35), greatest average carbon monoxide concentrations occurred at wind directions of southwest through east, similar to winter season measurements. These wind directions were associated with low wind speeds. The most frequent wind direction was westerly; the strongest winds also appeared from the west, tending to dilute carbon monoxide concentrations originating in the western quadrant, downtown South Charleston. The effect of wind speed on carbon monoxide concentrations is shown in Figure 4-36. An increase in wind speed causes a decrease in pollutant concentration.

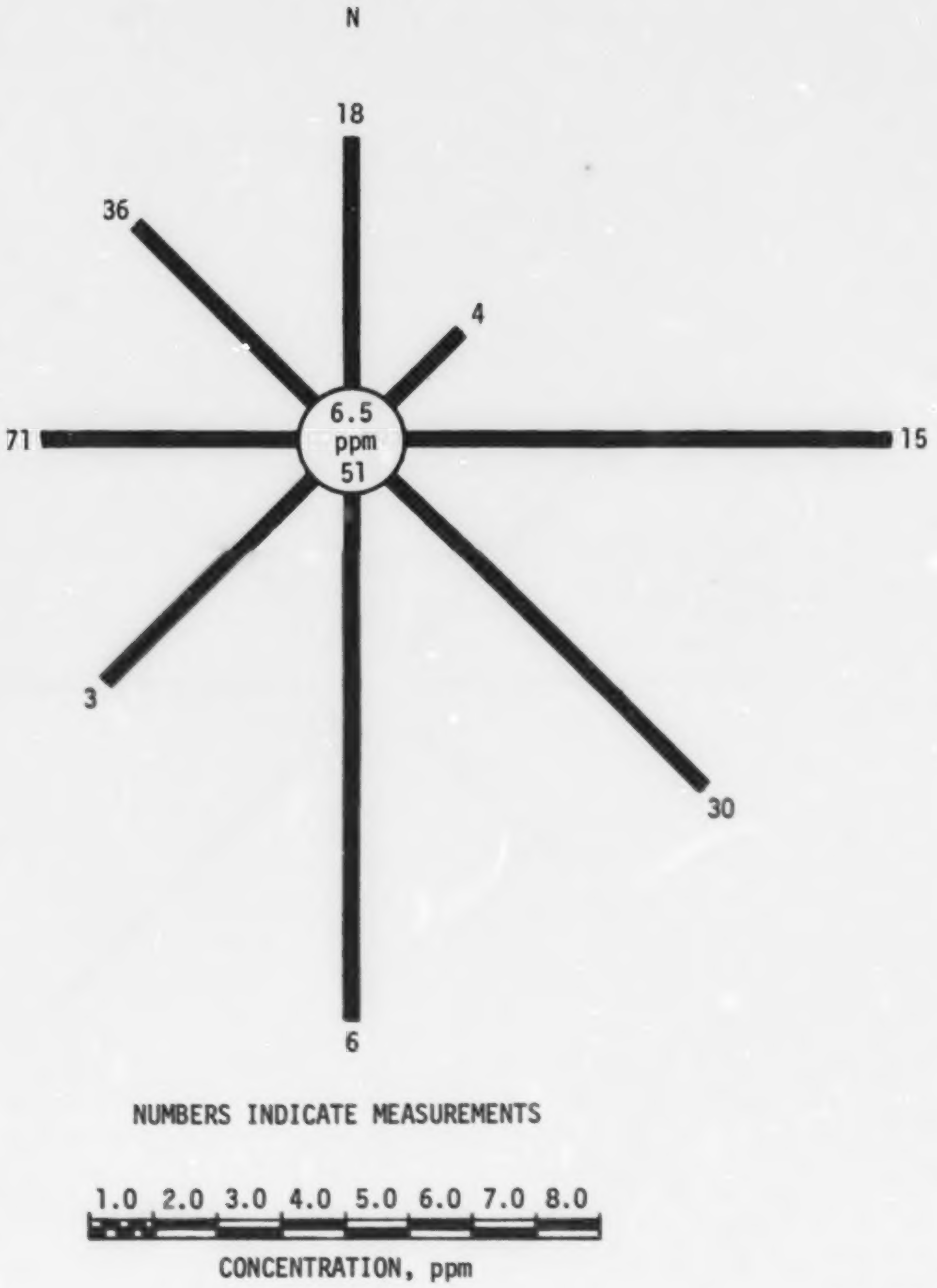


Figure 4-34. Carbon monoxide pollution rose for South Charleston, February and March, 1965.

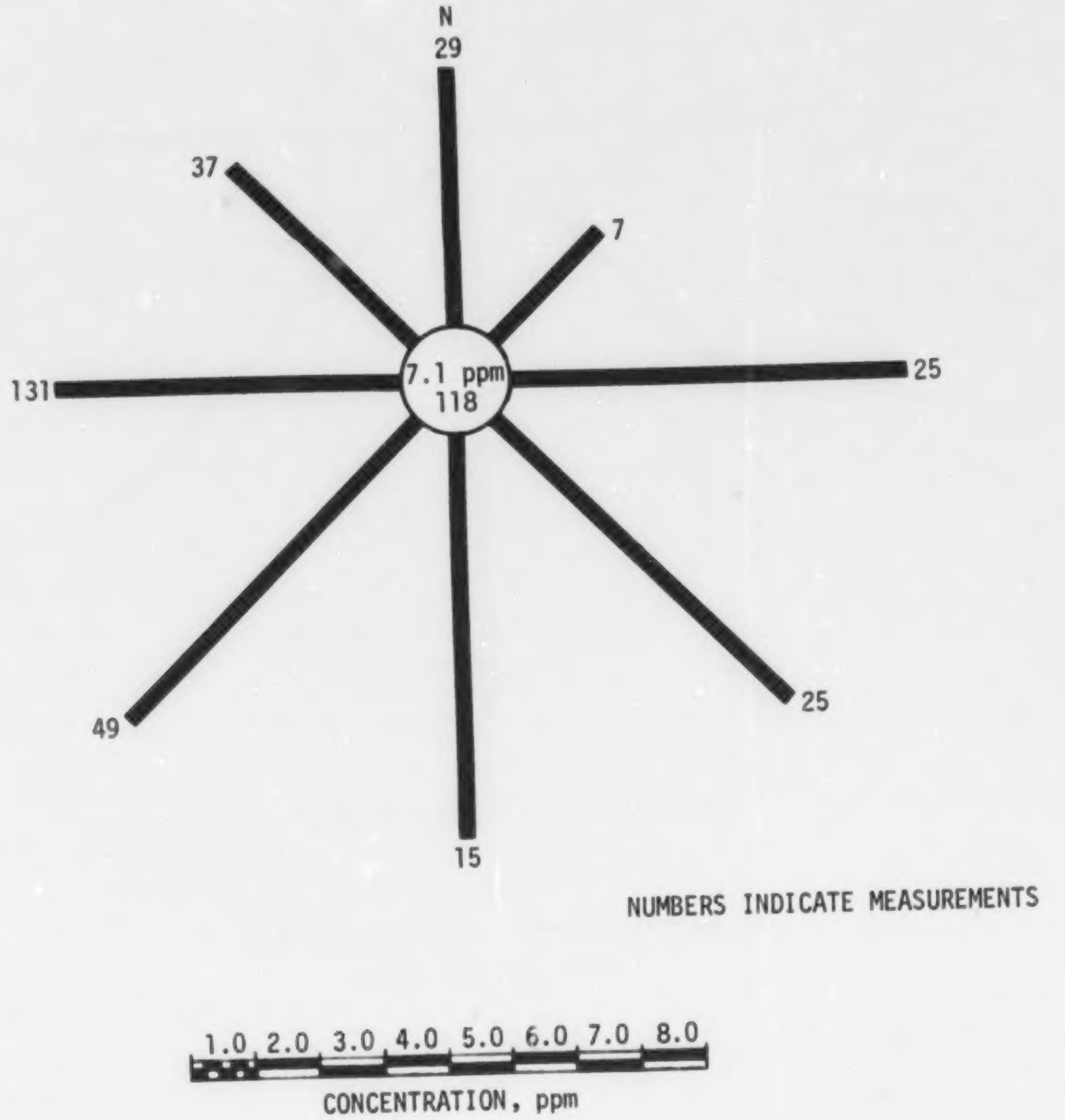


Figure 4-35. Carbon monoxide pollution rose for South Charleston, summer 1965.

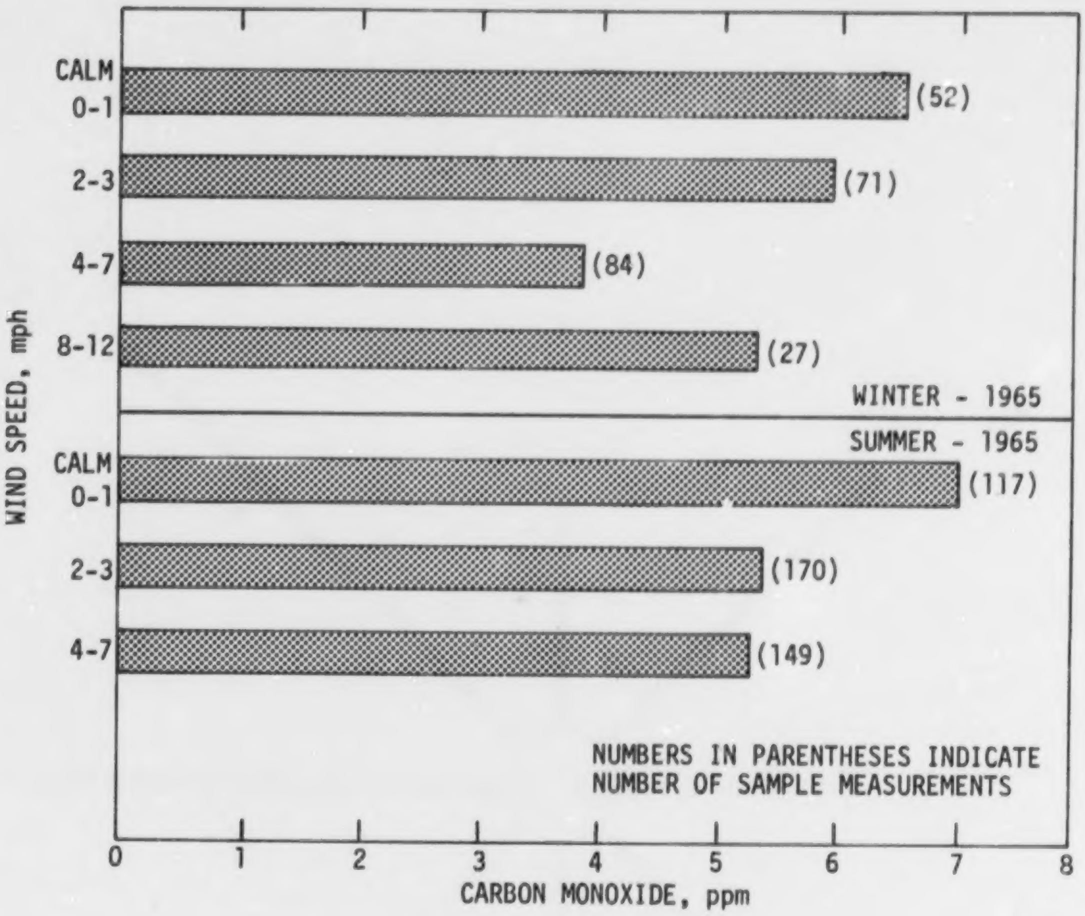


Figure 4-36. Relationship of carbon monoxide concentrations to wind speed for South Charleston.

In North Charleston during the spring sampling period, the prevailing valley drainage winds (light winds) are northeasterly, Figure 4-37. These light winds produce the greatest average carbon monoxide concentration when the wind direction is northeast and east. Principal highways are located northwest through east and the principal industrial sources are located southwest of the sampling site. Since relatively low carbon monoxide concentrations occurred when the wind direction was southwest, and the higher concentrations were recorded when the winds were from the northeast, the principal sources affecting the mobile laboratory there appear to be non-industrial. Data for North Charleston during the fall of 1965, Figure 4-38, indicate that the same relationships between carbon monoxide concentration, local meteorology, and possible sources would also apply. Wind speed and average pollutant concentrations show an inverse relationship as would be expected for pollution emissions at or near ground level, Figure 4-39.

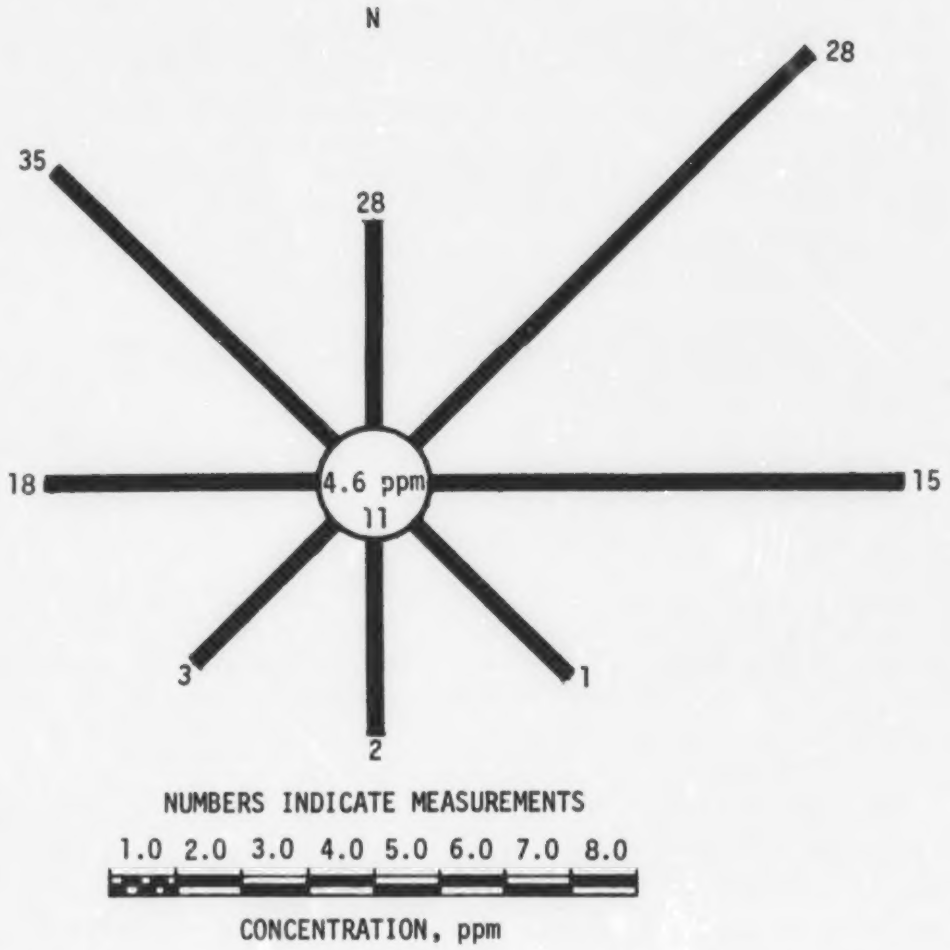


Figure 4-37. Carbon monoxide pollution rose for North Charleston, March and May 1965.

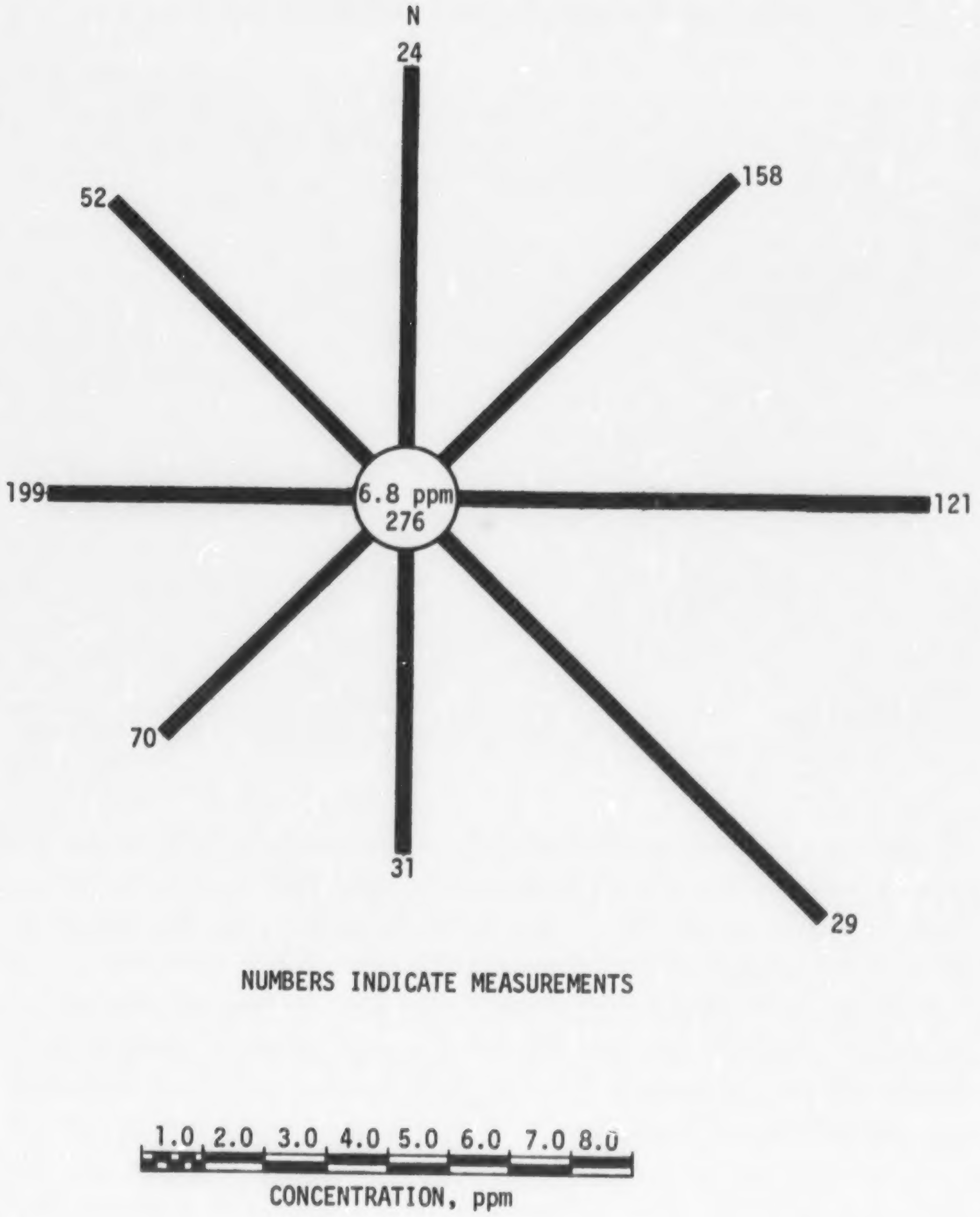


Figure 4-38. Carbon monoxide pollution rose for North Charleston, November and December 1965.

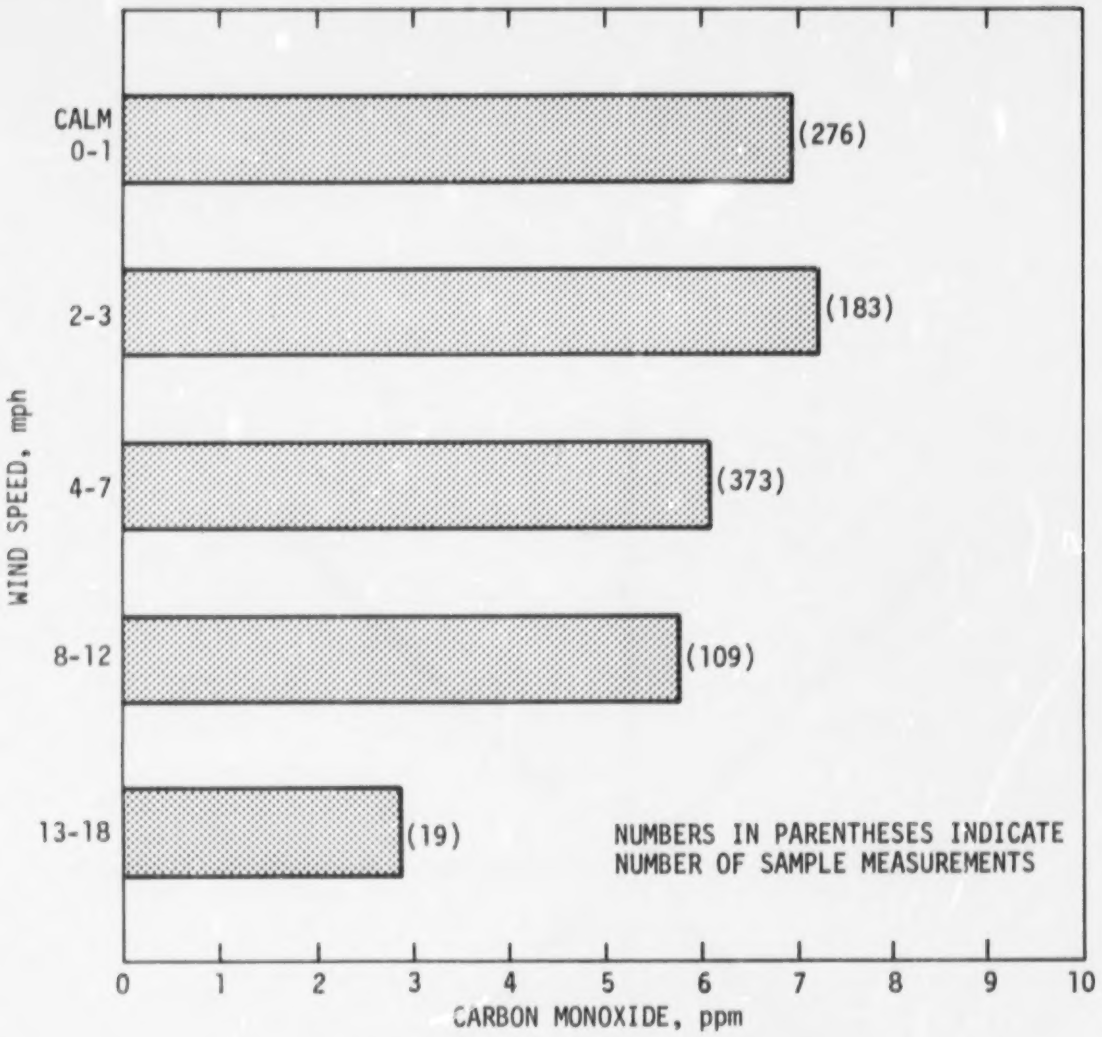


Figure 4-39. Relationship of carbon monoxide concentrations to wind speed for North Charleston, November - December 1965.

Summaries of carbon monoxide data from CAMP stations for 1964 and 1965 are presented in Tables 4-42 and -43, respectively. A comparison of the CAMP data with study data indicates that monthly concentrations found in the Kanawha Valley are greater than the maximum monthly concentrations reported in Washington, D. C. (1965, 5 ppm) and Cincinnati, Ohio (1965, 5 ppm). The study's monthly arithmetic mean averages are equal to or less than the yearly carbon monoxide averages reported for San Francisco (1964), Washington (1965), and Cincinnati (1965). The maximum daily average reported - South Charleston, fall of 1964 (16.1 ppm) - is 1/2 of the reported maximum daily value for the CAMP stations for 1964 and 1965 (32 ppm). The maximum daily value reported in the Kanawha Valley is equal to or less than the maximum daily values reported for 1964 in Chicago, Cincinnati, Denver, Philadelphia, and St. Louis.

Table 4-42. SUMMARY OF CARBON MONOXIDE DATA FROM CAMP STATIONS, 1964
(ppm)

City	Maximum		Yearly average	Percent of time concentration stated is exceeded			
	Daily	Monthly		90	50	10	1
Chicago	27	17	12	4	11	21	32
Cincinnati	17	11	6	2	5	12	18
Philadelphia	21	13	17	2	6	14	24
St. Louis	17	9	6	2	5	11	19
San Francisco	10	6	5	2	5	8	14
Washington	13	6	6	3	5	8	15

Table 4-43. CARBON MONOXIDE DATA FROM CAMP STATIONS, 1965
(ppm)

City	Maximum		Yearly average	Percent of time concentration stated is exceeded			
	Daily	Monthly		90	50	10	1
Chicago	32	21	17	9	16	26	38
Cincinnati	16	5	4	2	4	7	13
Denver	20	10	7	2	6	14	26
Philadelphia	19	11	8	4	8	13	19
St. Louis	15	10	7	2	6	12	21
Washington	10	5	4	2	3	6	13

The highest 1-percent values for downtown Charleston, winter 1964-1965, South Charleston, fall 1964, and North Charleston, winter 1965, are equal to or exceed the highest 1-percent concentrations reported for all CAMP stations with the exception of Chicago, Philadelphia, and St. Louis (1965) stations. This would indicate that while the average monthly carbon monoxide concentrations are equal to or less than the average concentrations reported for the CAMP network, relatively high concentrations of carbon monoxide occur in the valley at greater frequency than at most of the CAMP stations.

The daily maximum and highest 10 percent values in the study should be relatively low (other things being equal), because the study station were not operated a full year at each location as were the CAMP stations. The concentrations measured in the valley, however, do not exceed present air quality standard or criteria and the maximum hourly concentration of 30.6 ppm is relatively low.

Nitrogen Dioxide Measurements

Method - Nitrogen dioxide was determined spectrophotometrically using a continuous analyzer. Nitrogen dioxide diazotizes and couples with the Saltzman reagent to produce a characteristic red dye. The instrument was calibrated at regular intervals using nitrogen dioxide-air mixtures standardized by means of the manual Saltzman procedure.[33] Instrument response was occasionally compared to nitrogen dioxide measurements obtained by use of the manual Saltzman procedure.

Results - Air quality criteria for nitrogen dioxide are presented in Table 4-44. Data obtained for nitrogen dioxide in the study area are summarized in Table 4-45. The California standard was exceeded at the South Charleston, Nitro, and Kanawha City stations. The Colorado standard was exceeded at all the sampling locations. The potential for photochemical smog in terms of nitrogen dioxide concentration exists.

Table 4-44. NITROGEN DIOXIDE AMBIENT AIR STANDARDS OR CRITERIA FOR AREAS IN THE UNITED STATES, 1966

Area	Standard or criteria, average concentration, ppm
California[34]	0.25 for 1 hour
Colorado[6]	For total oxides of nitrogen 0.1 for 1 hour for greater than 1 percent of the time in any 3 months

In South Charleston, during the fall, nitrogen dioxide concentrations did not vary significantly with wind speed or direction (Figures 4-40 and 41), indicating that sources of nitrogen dioxide pollution affecting the measuring site are a mixture of low and high (elevated) sources lying in all directions from the sampling site. The same relationship is inferred for Charleston, as is indicated in Figures 4-42 and -43, except at strong wind conditions (12 mph), which resulted in dilution of nitrogen dioxide concentration.

In North Charleston, during the spring, greatest average nitrogen dioxide concentration occurred when the wind direction was south to southwest, Figure 4-44. The frequency of occurrence of high wind speeds was greater from the southwest through west directions, Figure 4-21. The greatest average nitrogen dioxide concentrations occurred at these high wind speeds, as shown in Figure 4-45. Industrial sources lying in the southwesterly quadrant probably emit the nitrogen dioxide measured under these conditions. Comparison of the nitrogen dioxide and sulfur dioxide

Table 4-45. FREQUENCY DISTRIBUTION OF HOURLY NITROGEN DIOXIDE CONCENTRATIONS

Station location	Season	Number of measurements	Arithmetic mean, ppm	Geometric mean, ppm	Number of occurrences, 0.25 ppm	Maximum, (1-hour) ppm	Percent of time concentration (ppm) is exceeded		
							50	10	1
Charleston	Fall 1964	553	0.05	0.05	0	0.15	0.05	0.08	0.11
Charleston	Winter 1965	333	0.05	0.03	0	0.18	0.05	0.08	0.14
South Charleston	Fall 1964	514	0.06	0.05	5	0.39	0.06	0.10	0.26
South Charleston	Winter 1965	312	0.08	0.06	5	0.35	0.07	0.17	0.33
South Charleston	Summer 1965	427	0.03	0.02	0	0.15	0.03	0.07	0.09
Nitro (Post Office)	Fall 1964	391	0.10	0.09	14	0.44	0.09	0.17	0.32
Nitro (Junior high school)	Spring 1965	297	0.03	0.03	0	0.19	0.02	0.08	0.16
Kanawha City	Winter 1965	276	0.16	0.12	6	0.44	0.12	0.31	0.41
Kanawha City	Summer 1965	130	0.09	0.07	10	0.31	0.07	0.23	0.30
Kanawha City	Fall 1965	391	0.09	0.04	11	0.39	0.07	0.19	0.28
North Charleston	Spring 1965	710	0.09	0.03	0	0.23	0.05	0.14	0.19
North Charleston	Fall 1965	423	0.03	0.02	0	0.17	0.02	0.08	0.12

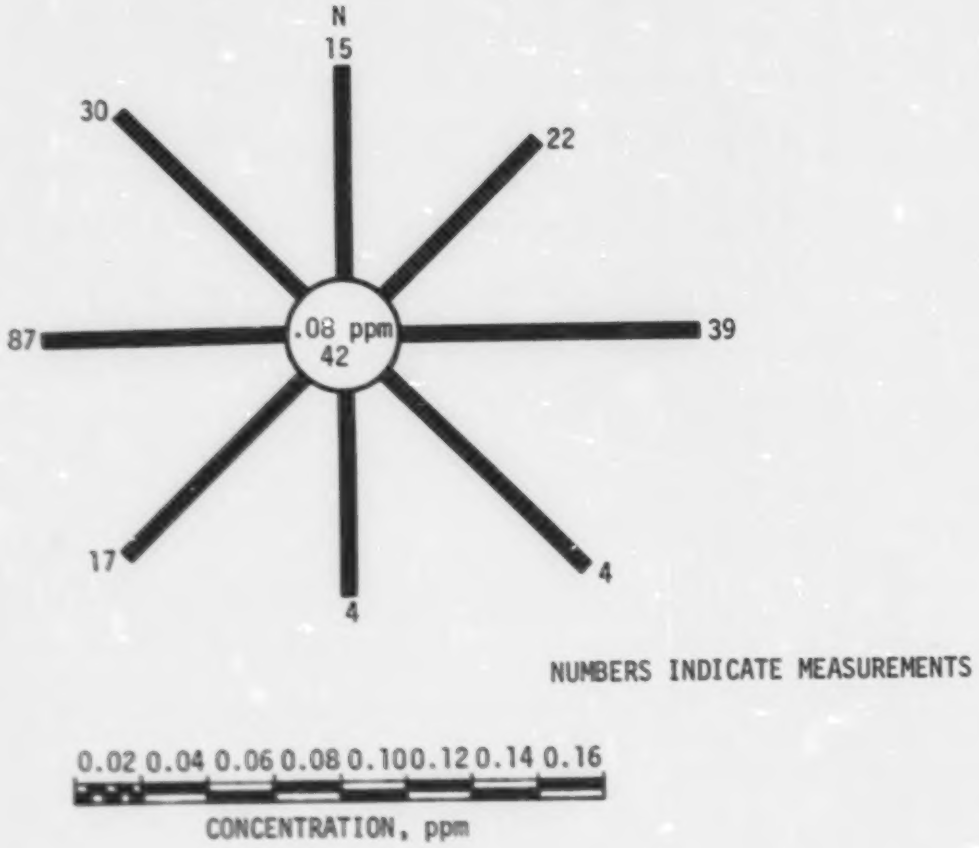


Figure 4-40. Nitrogen dioxide pollution rose for South Charleston, October and November 1964.

measurements (Figures 4-19, -20, -44, and -45), indicate that high concentrations are probably from the same or adjacent sources.

In Kanawha City, during the winter, nitrogen dioxide concentrations varied directly with wind speed, as indicated in Figure 4-46. The greatest concentrations occurred at wind speeds of 8-12 mph. These wind speeds were associated with wind directions of south and northwest, Figure 4-47. These data indicate that the measured concentrations are due to different sources both upriver and downriver. Relating nitrogen dioxide concentration to wind direction also shows that sources lying in the northwest and southeast quadrant (upriver and downriver) contributed mainly to the high nitrogen dioxide concentrations measured, Figure 4-48.

In Nitro, during the spring sampling period, measurements of NO_2 did not vary significantly with wind direction except that nitrogen dioxide concentration was smaller with a westerly wind direction, Figure 4-49. The relationship between wind speed and average nitrogen dioxide concentration indicates that: at low speeds

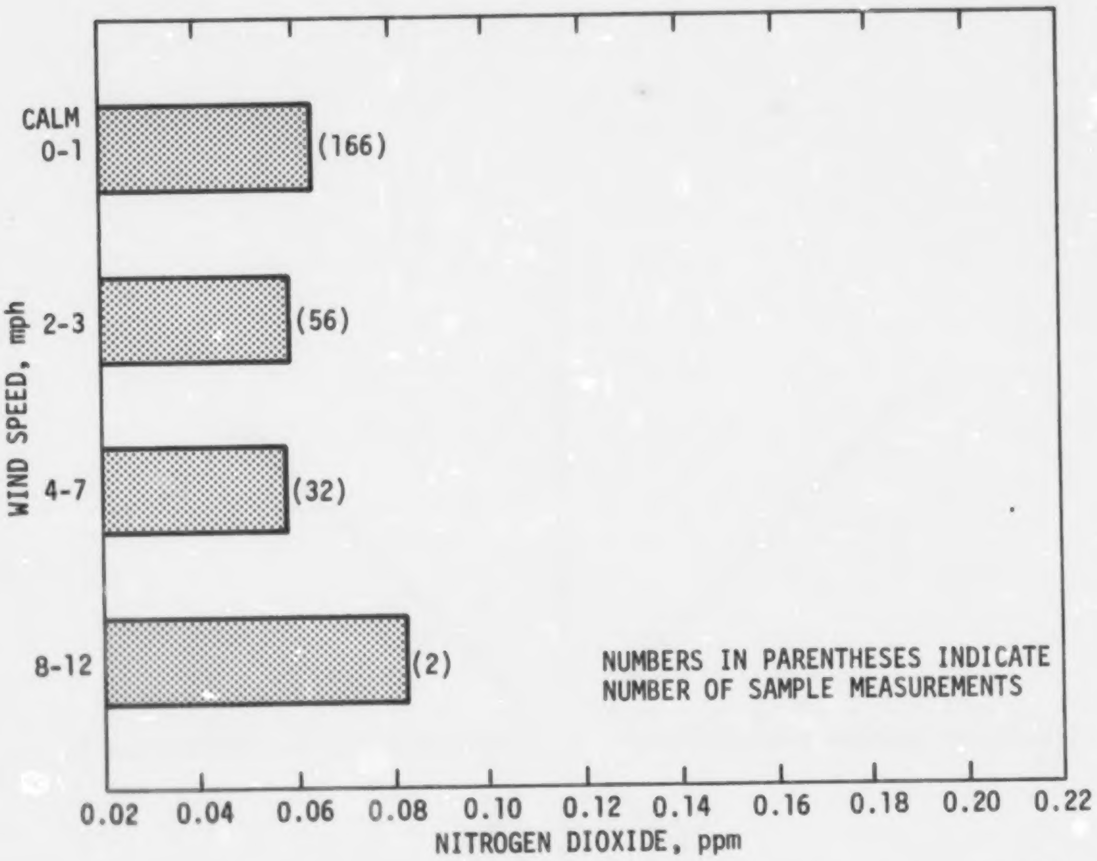


Figure 4-41. Relationship of nitrogen dioxide concentrations to wind speed, South Charleston, October - November 1964.

(1-4 mph), stratification of the air occurs, carrying the nitrogen dioxide above the sampling site; at moderate speeds (4-7 mph) more of the nitrogen dioxide is brought down to the surface at the measuring site; and at high wind speeds (8-12 mph) the pollutants are significantly diluted, Figure 4-50.

A comparison of data from each mobile laboratory study, Table 4-45, with the 1964 and 1965 maximum monthly averages and cumulative frequency distribution data for the CAMP network stations (Tables 4-46 and -47), indicates that, with the exception of 1964 averages measured for Chicago and San Francisco, 7 out of the 12 monthly mobile laboratory studies exceeded the maximum monthly averages reported. Also, the mobile laboratory measurements in Kanawha City exceeded all the maximum monthly averages reported for the entire CAMP network. The maximum 1 percent of the nitrogen dioxide values found in the valley, when compared with those reported for the CAMP station, reveals that the values found at South Charleston (with the exception of the summer of 1965), Nitro Post Office, and Kanawha City exceeded the 1 percent concentrations reported for all CAMP stations. The comparison with CAMP data indicates that a potential nitrogen dioxide-oxidant problem exists in the Charleston area.

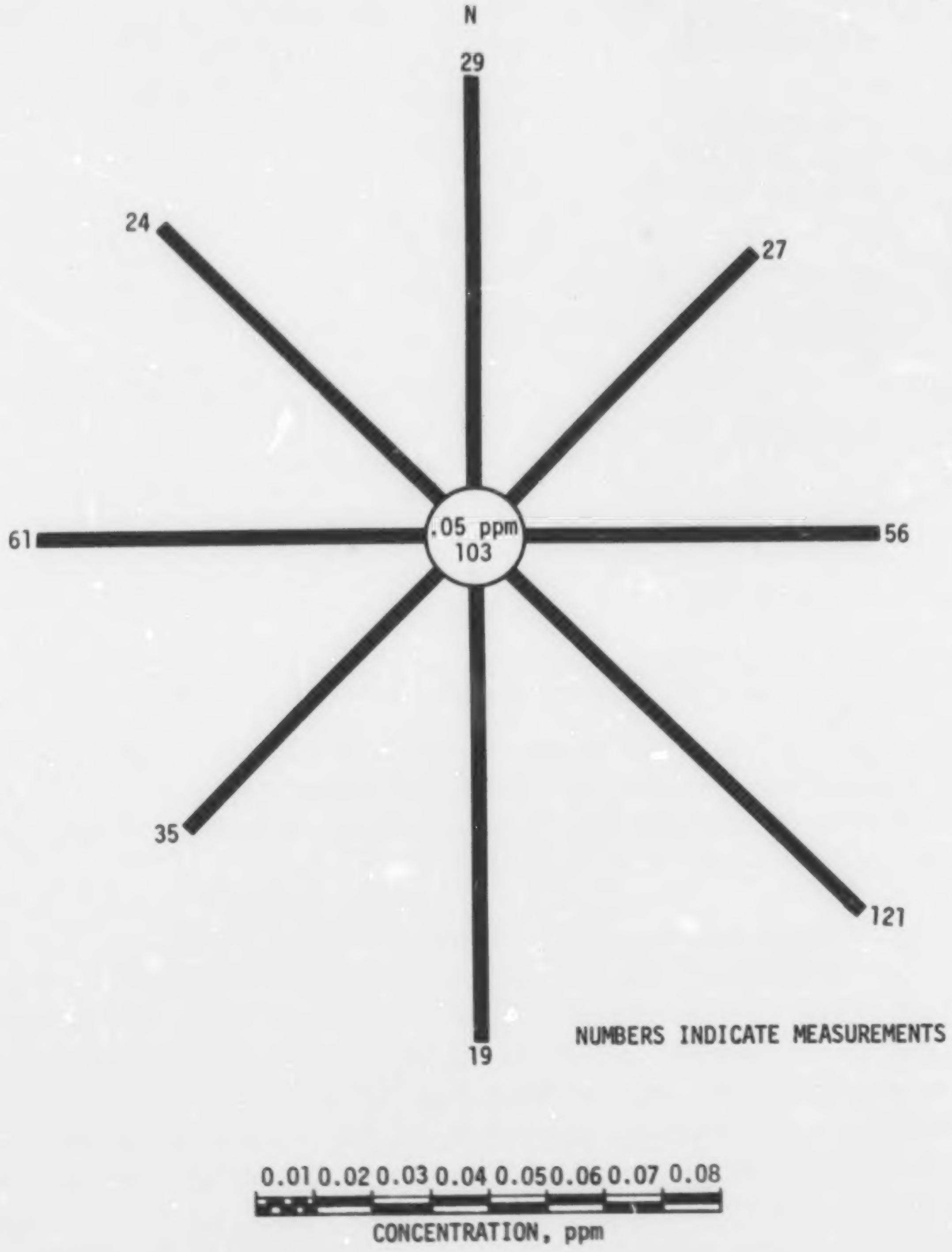


Figure 4-42. Nitrogen dioxide pollution rose for Charleston, August and September 1964.

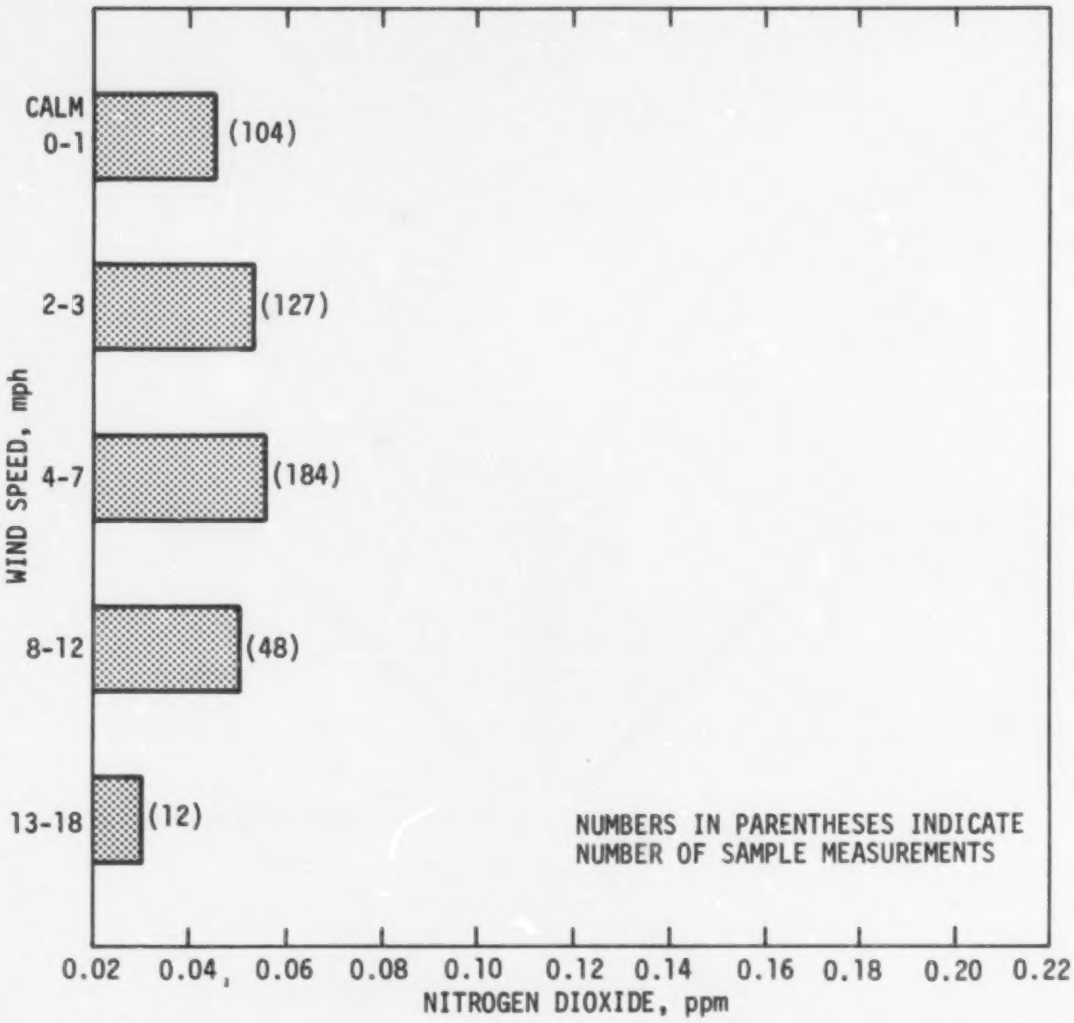


Figure 4-43. Relationship of nitrogen dioxide concentrations to wind speed, Charleston, Summer - Fall 1964.

The nitrogen oxide values measured during the 1950-1951 Air Pollution Study, Table 4-48, are generally higher than the nitrogen dioxide values measured during the 1964-1965 study. The difference in concentrations measured by these two studies probably represents the difference caused by sampling and analytical procedures.

Oxidant Measurements

Method - Oxidants were determined by using a continuous coulometric analyzer containing potassium iodide-potassium bromide reagent in the electro-analytical cell. Sulfur dioxide interferes quantitatively in this reaction because the iodine liberated in the oxidation reaction is immediately reduced by any sulfur dioxide in the sample. To eliminate the interference of sulfur dioxide, the air sample is passed through a bed of chromium trioxide-treated filters before passage into the analyzer.[36] This treatment, however, also oxidizes nitrogen oxide to nitrogen dioxide,

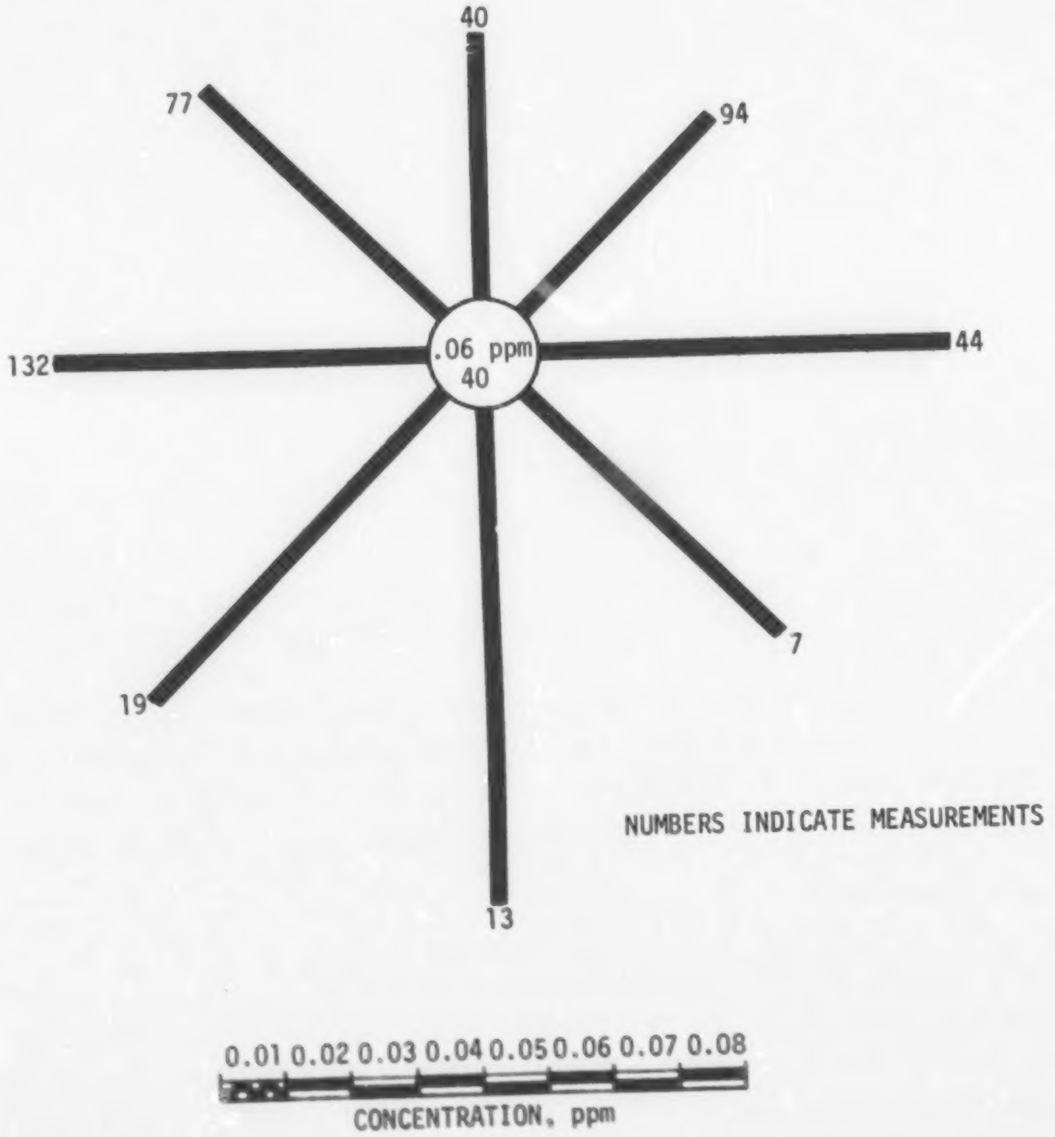


Figure 4-44. Nitrogen dioxide pollution rose for North Charleston, March and April 1965.

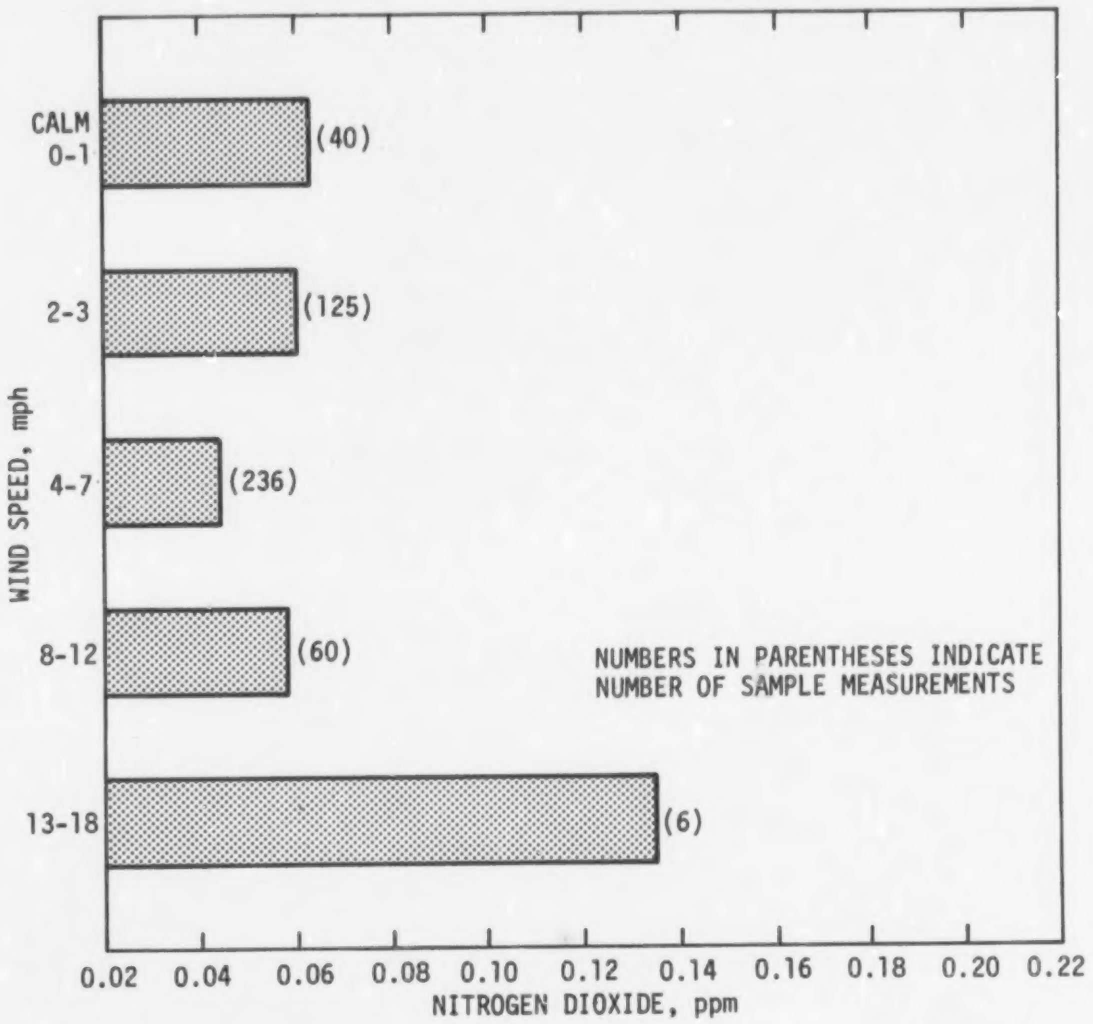


Figure 4-45. Relationship of nitrogen dioxide concentrations to wind speed, North Charleston, March - April 1965.

and the additive response of the analyzer to nitrogen dioxide is about 10 percent that of ozone. The instrument was calibrated at regular intervals using an ozone-air mixture prepared by irradiation of air with ultraviolet lamps and standardized by the neutral buffered potassium iodide method.[33]

Results - Data on oxidant concentration in the Kanawha Valley are summarized in Table 4-49. These data were examined in light of existing air quality criteria, Table 4-50. Air quality criteria for oxidants were not exceeded at any measurement site except North Charleston. Since these oxidant measurements in North Charleston were obtained in the spring and the late fall, there is the possibility that some or all of the high oxidant levels measured were not caused by photochemical reactions. The sources of the high oxidant concentrations measured are probably the emissions of oxidizing pollutants from industrial processes.

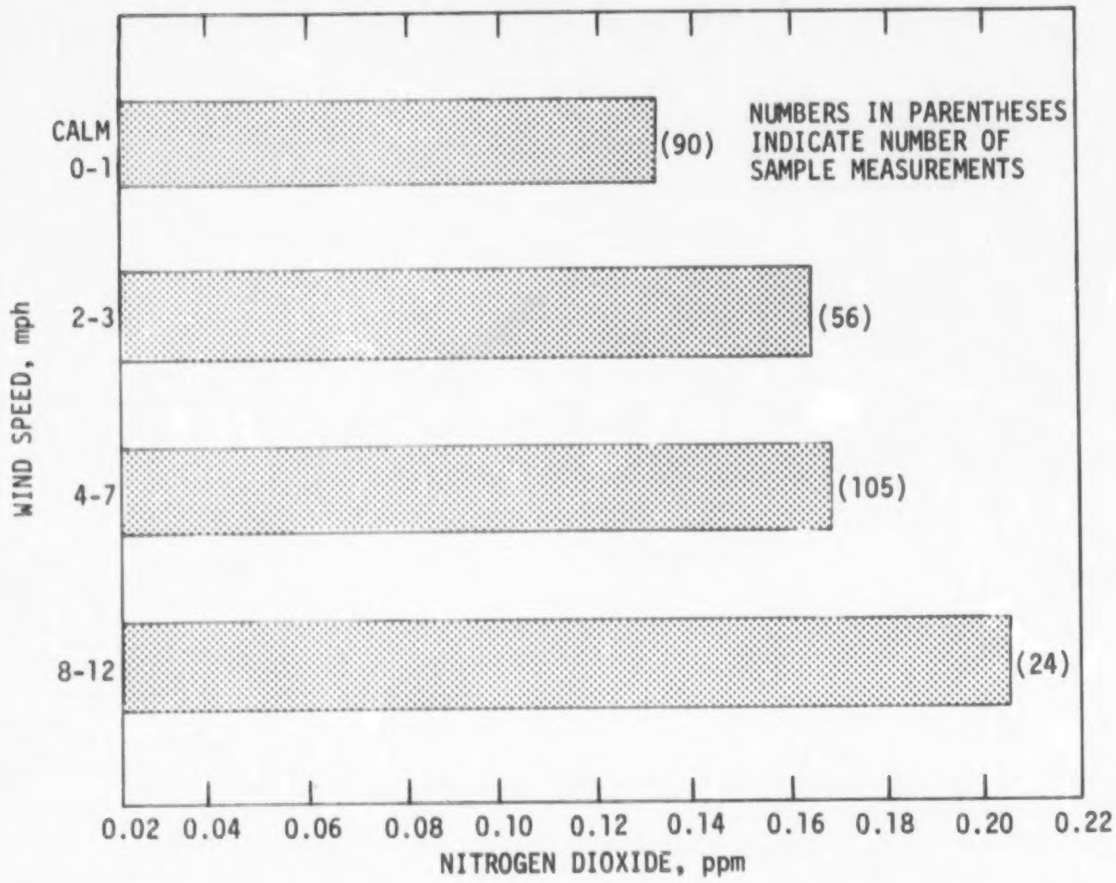


Figure 4-46. Relationship of nitrogen dioxide concentrations to wind speed, Kanawha City, January - February 1965.

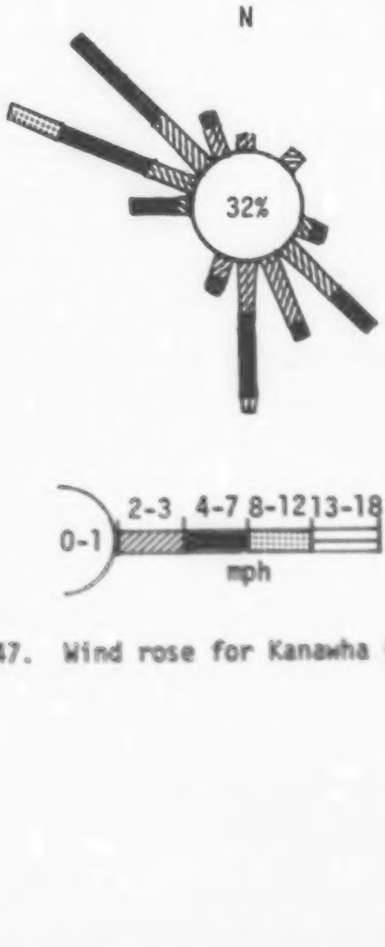


Figure 4-47. Wind rose for Kanawha City, winter 1965.

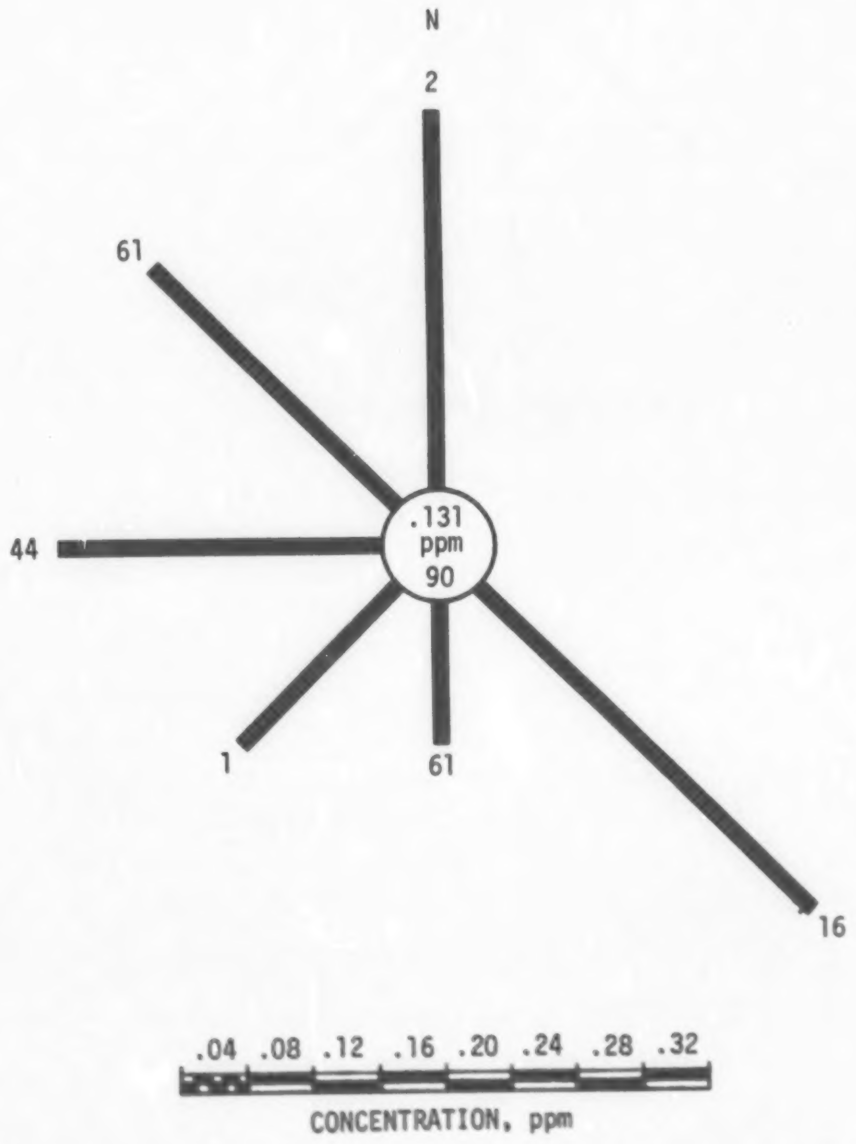


Figure 4-48. Relationship of nitrogen dioxide concentration to wind direction in Kanawha City, winter 1965.

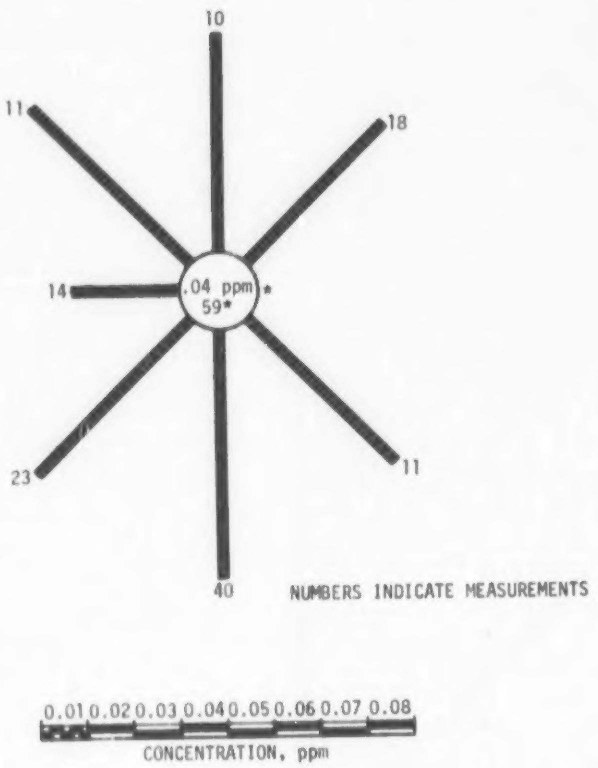


Figure 4-49. Nitrogen dioxide pollution rose for Nitro, May and June 1965.

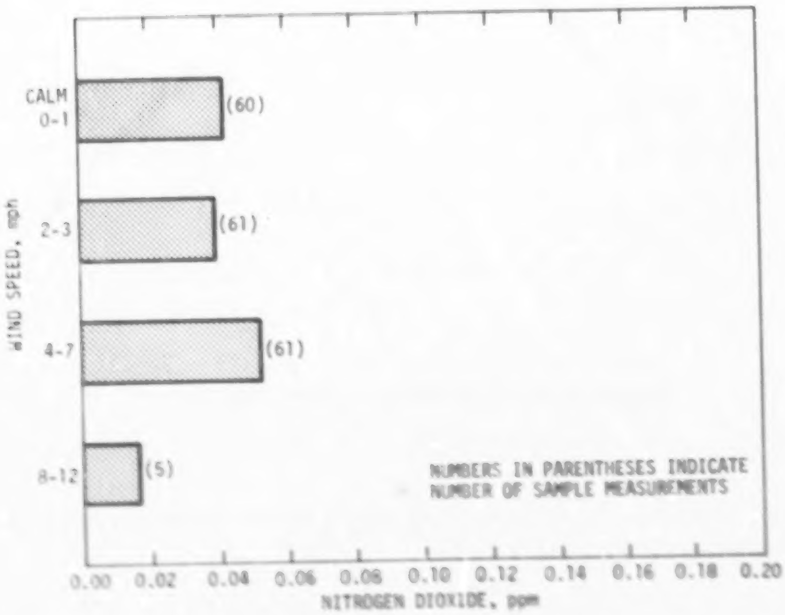


Figure 4-50. Relationship of nitrogen dioxide concentrations to wind speed, Nitro, May - June 1965.

Table 4-46. 1964 NITROGEN DIOXIDE DATA FROM THE CAMP NETWORK
(ppm)

City	Maximum		Yearly average	Percent of time concentration stated is exceeded			
	Daily	Monthly		90	50	10	1
Chicago	0.15	0.07	0.05	0.02	0.04	0.08	0.13
Cincinnati	0.10	0.05	0.03	0.01	0.03	0.06	0.10
Philadelphia	0.10	0.05	0.04	0.02	0.03	0.06	0.11
San Francisco	0.18	0.08	0.06	0.01	0.03	0.05	0.09
St. Louis	0.12	0.04	0.03	0.02	0.04	0.09	0.21
Washington	0.10	0.04	0.04	0.02	0.03	0.06	0.10

Table 4-47. 1965 NITROGEN DIOXIDE DATA FROM THE CAMP STATIONS
(ppm)

City	Maximum		Yearly average	Percent of time concentration stated is exceeded			
	Daily	Monthly		90	50	10	1
Chicago	0.09	0.05	0.04	0.03	0.04	0.06	0.10
Cincinnati	0.08	0.04	0.03	0.02	0.03	0.05	0.08
Philadelphia	0.07	0.04	0.03	0.02	0.03	0.06	0.10
Denver	0.09	0.04	0.03	0.02	0.03	0.06	0.10
St Louis	0.05	0.03	0.02	0.01	0.02	0.04	0.07
Washington	0.07	0.04	0.03	0.02	0.03	0.05	0.09

Excessive oxidant concentrations in North Charleston were related to meterological factors, Table 4-51. Greatest concentrations were measured after dark on November 2; thus these oxidant measurements cannot be directly related to photochemical smog production, but are probably caused by chemical oxidant emissions. On several other occasions, high oxidant concentrations occurred under cloudy sky conditions so that photochemical smog formation of oxidants was also unlikely. There was no single wind directionality at the time of high oxidant concentration; wind directions were northeast, southeast, and southwest, indicating perhaps that the high oxidant concentrations measured are due to pollutant emissions from several sources or even possibly to area-wide photochemically produced oxidants. Wind speeds associated with these measurements were generally 3 to 7 mph, which are average or above average for the Kanawha Valley, indicating possible direct transport of oxidant from source to receptor.

Table 4-48. NITROGEN OXIDE DATA FROM 1950-1951 KANAWHA VALLEY AIR POLLUTION STUDIES (ppm)

	West Virginia Bureau of Industrial Hygiene[a]				Kettering[b] Laboratory	
	8 a.m. to 4 p.m.		4 p.m. to 10 p.m.			
Station	Average	Maximum	Average	Maximum	Average	Maximum
Kanawha City	0.08	0.27	0.11	0.26	0.10	0.28
Charleston	0.12	0.26	0.20	0.92	0.12	0.37
South Charleston	0.12	0.30	0.09	0.12	0.17	0.40
					0.09	0.24
North Charleston					0.09	0.24
					0.25[c]	0.56[c]
St. Albans	0.09	0.26	0.10	0.19	0.09	0.58
Institute	0.07	0.14	0.13	0.29	0.21	0.50
Belle			0.15	0.78		0.00
Glass Plants (Kanawha City)					0.13	0.23

[a] For sampling period of January 16 to June 11, 1951.

[b] For sampling period of December 1950 through June 1951.

[c] Sampling upwind of industrial complex.

A comparison of oxidant concentrations obtained during the 1964-1965 Kanawha Valley Air Pollution Study, Table 4-49, with the 1964 and 1965 CAMP network stations, Tables 4-52 and -53, indicates that levels measured in the valley are less than the yearly averages and approximately 1/2 to 1/4 of the monthly maximum averages reported at the CAMP network stations. As mentioned with respect to measurements of other gases, the CAMP stations operated for longer periods than did the study's mobile sampling station at each site. A review of the maximum 1 and 10 percent values from the cumulative frequency distribution data for both the valley and the CAMP stations, reveals that all the valley stations, with the exception of North Charleston, are below those reported by the CAMP network. The 1 percent value reported by the North Charleston station in the spring of 1965 was equivalent to the reported CAMP concentrations, while the 10 percent value reported for both the North Charleston sampling sites was comparable to those found at the CAMP stations. A review of these comparisons of oxidant measurements indicates that photochemical smog was not found to be a problem in the study area.

Table 4-49. SUMMARY OF HOURLY OXIDANT DATA

Station location	Season	Number of measurements	Arithmetic mean, ppm	Geometric mean, ppm	Number of occurrences, 0.15 ppm	Number of occurrences, 0.10 ppm	Maximum, ppm	Percent of time concentration (ppm) is exceeded		
								50	10	1
Charleston	Fall '64	974	0.00	0.01	0	0	0.05	0.01	0.01	0.03
North Charleston	Fall '64	359	0.01	0.01	0	0	0.02	0.01	0.01	0.01
North Charleston	Winter '65	594	0.01	0.01	0	0	0.03	0.01	0.01	0.02
North Charleston	Summer '65	666	0.01	0.01	0	0	0.08	0.01	0.01	0.02
Nitro	Fall '64	554	0.01	0.01	0	0	0.07	0.01	0.02	0.06
Nitro	Spring '65	618	0.01	0.01	0	0	0.07	0.01	0.02	0.03
Kansas City	Winter '65	162	0.01	0.01	0	0	0.01	0.01	0.01	0.01
Kansas City	Summer '65	401	0.01	0.01	0	0	0.01	0.01	0.01	0.01
Kansas City	Fall '65	139	0.01	0.01	0	0	0.05	0.01	0.02	0.05
North Charleston	Spring '65	852	0.02	0.02	2	7	0.20	0.01	0.04	0.10
North Charleston	Fall '65	915	0.02	0.02	2	3	0.41	0.03	0.04	0.07
Marmet	Winter '66	568	0.01	0.01	0	0	0.01	0.01	0.01	0.01

Table 4-50. AMBIENT AIR STANDARDS OR CRITERIA FOR OXIDANTS FOR AREAS IN THE UNITED STATES, 1966

Areas	Standard or criteria, average concentration, ppm
California[34]	0.15 for 1 hour (adverse level).
Colorado[6]	0.10 for 1 hour for greater than 1 percent of time in any 3-month period.
New York[7]	0.15 for 1 hour. 0.10 for 4 hours for certain regions.
St. Louis[10] (Metropolitan)	0.15 for 1 hour.

Table 4-51. RELATIONSHIP OF OXIDANT CONCENTRATIONS GREATER THAN 0.1 PPM TO WIND SPEED AND DIRECTION IN NORTH CHARLESTON

Oxidant concentration, ppm	Date	Time	Wind speed, mph	Wind direction, angular degrees	Cloud cover, tenths
0.15	4/5/65	1200	3.0	30	9
0.10	4/8/65	1200	7.0	220	10
0.17	4/14/65	1000	3.5	220	2
0.13	4/14/65	1100	4.0	140	3
0.11	4/14/65	1800	2.0	40	10
0.20	4/22/65	0800	2.0	240	9
0.11	4/25/65	1500	4.5	270	9
0.41	11/2/65	1900	5.5	45	0
0.22	11/2/65	2000	5.0	55	0
0.10	12/10/65	1300	3.0	135	10

Hydrogen Sulfide Measurements

Method - Hydrogen sulfide was measured quantitatively by means of an impregnated filter-tape automatic analyzer which included a light source, photo cell, and recorder.[22,26] Light transmittance measurements of the lead sulfide formed on the filter tape were recorded continuously. The calibration curve supplied by the manufacturer for given air flow rates was used since the curve had been checked previously using hydrogen sulfide gas mixtures and good agreement had been obtained. Instrument response was occasionally checked against hydrogen sulfide measurements determined by means of the methylene blue method.[37]

Table 4-52. 1964 OXIDANT DATA FROM THE CAMP STATIONS (ppm)

City	Maximum		Yearly average	Percent of time concentration stated is exceeded			
	24-hour average	Monthly average		90	50	10	1
Chicago	0.07	0.04	0.02	0.00	0.01	0.05	0.08
Cincinnati	0.08	0.06	0.02	0.00	0.02	0.05	0.12
Philadelphia	0.09	0.05	0.02	0.00	0.02	0.05	0.12
San Francisco	0.05	0.03	0.02	0.00	0.02	0.05	0.10
St. Louis	0.07	0.04	0.03	0.01	0.02	0.08	0.07
Washington	0.08	0.04	0.03	0.00	0.02	0.06	0.10

Table 4-53. 1965 OXIDANT DATA FROM THE CAMP STATIONS (ppm)

City	Maximum		Yearly average	Percent of time concentration stated is exceeded			
	24-hour average	Monthly average		90	50	10	1
Chicago	0.08	0.05	0.02	0.00	0.02	0.05	0.09
Cincinnati	0.10	0.04	0.03	0.01	0.03	0.06	0.09
Denver	0.08	0.05	0.03	0.01	0.03	0.06	0.12
Philadelphia	0.23	0.07	0.03	0.01	0.02	0.06	0.17
St. Louis	0.07	0.04	0.03	0.01	0.03	0.06	0.10
Washington	0.08	0.05	0.03	0.01	0.02	0.06	0.11

Results - Ambient air quality criteria for hydrogen sulfide are presented in Table 4-54. The greatest hydrogen sulfide concentration measured during the study was 0.002 ppm, based on a 2-hour averaging time, and the highest frequency of occurrence of measurable quantities of hydrogen sulfide occurred in Nitro, Table 4-55. Assuming that the ratio of peak to mean for 1-hour concentrations did not exceed 50, existing ambient air quality criteria were not exceeded during the time that measurements were made. Paint-blackening incidents have occurred in the past in the study area, which may be attributed to atmospheric hydrogen sulfide, but none occurred during the time that measurements were made.

Table 4-54. HYDROGEN SULFIDE AMBIENT AIR STANDARDS OR CRITERIA FOR AREAS IN THE UNITED STATES, 1966

Area	Standard or criteria, average concentration, ppm
California[34]	0.1 for 1 hour
New York[7]	0.1 for 1 hour
St. Louis[10]	0.03 for 1/2 hour for more than twice in 5 consecutive days
	0.05 for 1/2 hour for more than twice in a year
Pennsylvania[9]	0.005 for 24 hours
	0.1 for 1 hour

Instrumentally detectable and non-detectable hydrogen sulfide concentrations in Nitro were related to prevailing wind direction and speed as shown in Table 4-56. These detectable concentrations occurred most frequently during nighttime hours at light-wind conditions (less than 2 mph). When wind speeds were high enough to assign meaningful directions, the wind direction during the time of occurrence of detectable hydrogen sulfide concentration was south to southwest and north. Non-detectable hydrogen sulfide measurements were also related to wind speed and direction on the same days that hydrogen sulfide concentrations were detectable for several 2-hour periods. These non-detectable hydrogen sulfide concentrations occurred most frequently when wind speeds were greater than 2 mph. These relationships suggest that the hydrogen sulfide measured is due to low-level (concentration) sources of emission. Possible sources of this type may be from biological decomposition of industrial waste in ponds or from sewage treatment facilities. Emissions from elevated industrial sources located north of the sampling site may have contributed to the hydrogen sulfide measured, however.

A comparison of hydrogen sulfide concentrations measured during the 1950-51 studies with concentrations measured during the 1964-1965 study indicates that concentrations measured in the Kanawha Valley have decreased. The maximum average concentration (0.077 ppm), measured by the Kettering Laboratory, and the maximum concentration (0.267 ppm), measured by State Bureau of Industrial Hygiene, were found downwind from the Nitro industrial complex. Both used the same sampling procedure. Other average concentrations of hydrogen sulfide were found at the following stations: Belle, 0.017 ppm, and St. Albans, 0.011 ppm. These results would seem to confirm industrial reports that several of the former hydrogen sulfide sources

Table 4-55. FREQUENCY DISTRIBUTION OF 2-HOUR HYDROGEN SULFIDE CONCENTRATIONS

Station location	Season	Number of measurements	Arithmetic mean, ppm	Geometric mean, ppm	Maximum, ppm	Percent of time stated concentration (ppm) is exceeded		
						50	10	1
Nitro (Junior high school)	Spring '65	285	0.001	0.001	0.002	0.001	0.001	0.002
North Charleston	Fall '65	247	0.000	0.000	0.002	0.001	0.001	0.002
Marmet	Winter '66	169	0.000	0.000	0.002	0.001	0.001	0.002

were now controlled. Hydrogen sulfide is still a problem, as evidenced by a paint-blackening episode in the St. Albans area and numerous hydrogen sulfide odor complaints and odor observations in the Nitro and the North and South Charleston areas.

Table 4-56. RELATIONSHIP OF MEASURABLE HYDROGEN SULFIDE CONCENTRATION AND METEOROLOGY IN NITRO

		Detectable			Nondetectable	
Date	Time	Wind speed, mph	Wind direction, angular degrees	Time	Wind speed, mph	Wind direction, angular degrees
5/6/65	0600	2	180[a]	0000	2	180[a]
	0800	3.5	200	0200	2	90[a]
		2.5	220	0400	2	180[a]
	2200	2	N.A.[b]	1200	3	200
				1400	3	170
				1600	3.5	220
				1800	2	360[a]
				2000	2	50[a]
5/7/65	0000	2	180[a]	0800	3	180
	0200	2		1000	4	320
	0400	2	180[a]	1200	2.5	270
	0600	2	360[a]	1400	5.5	350
	2000	2	180[a]	1600	4.5	330
	2200	2	180[a]	1800	2	N.A.
5/8/65	0000	2	360[a]	0800	3	180
	0200	2	360[a]	1000	6.5	300
	0400	2	360[a]	1200	4	320
	0600	4	180[a]	1400	3.5	230
				1600	5	280
				1800	2	N.A.
				2000	4	170
				2200	2.5	190
5/18/65	0800	2.5	135			
5/26/65	1400	5.5	180			

[a] General Chemical Company wind instrument.

[b] N.A. = Not Assignable.

Sulfuric Acid Mist Measurements

Method - Sulfuric acid mist concentration was determined on a 24-hour average basis in North Charleston during the fall sampling period using the method of Commons.[38] Atmospheric particulates were collected by filtration for 24 hours through Whatman #42 filter paper, and the amount of particulate acid present was determined by immersing the sample in a known excess of sodium tetraborate and back-titrating with standard acid.

Results - Data obtained are summarized in Table 4-57. Sulfuric acid concentration ranged from 0.6 to 3.6 μg/m^3. Several hourly samples were also obtained in North Charleston at two other sampling sites, Table 4-58. Sulfuric acid mist concentrations obtained were 3.8, 9.3, and 4.1 μg/m^3 respectively. These hourly and daily sulfuric acid concentrations did not exceed ambient air quality objectives of New York State or of the St. Louis Metropolitan area as shown in Table 4-59. Further measurements would be required to determine whether pollution due to sulfuric acid mist is a problem.

Acid mist plumes from the acid plant and acid concentrators are frequently observed to fumigate the North and West Charleston areas, causing numerous complaints of throat and eye irritation. Operating equipment malfunctions and winds of 4 mph or greater are the usual causes of these acid mist fumigations.

Table 4-57. 24-HOUR SULFURIC ACID MIST CONCENTRATIONS IN NORTH CHARLESTON

November 1965 (day)	Concentration, μg/m^3
1	2.2
3	1.5
4	0.8
5	2.7
6	1.7
7	1.8
8	1.6
9	0.8
11	1.1
12	0.6
13	1.0
14	1.3
15	3.6
16	2.0
17	1.2
Arithmetic mean	1.6

Table 4-58. 1-HOUR SULFURIC ACID MIST CONCENTRATIONS IN NORTH CHARLESTON

Date	Starting time	Sampling location	Concentration, $\mu g/m^3$	Wind speed, mph	Wind direction, angular degrees
11/12/65	1055	7th Ave. and James St.	3.8	4.5	125
11/15/65	1016	7th Ave. and James St.	9.3	2.0	90
11/17/65	1126	4th Ave. and Patrick St.	4.1	11.5	270

Table 4-59. AMBIENT AIR QUALITY STANDARDS OR CRITERIA FOR SULFURIC ACID MIST FOR AREAS IN THE UNITED STATES, 1966

Area	Standard or criteria average concentration, $\mu g/m^3$
New York State	100 for 24 hours
St. Louis (Metropolitan)	4 annual averages 10 for 24 hours, once in any 90 days 30 for 30 minutes or more, once in any 90 days

Total Aliphatic Aldehyde Measurements

Method - Several short-term samples (30-minutes) were collected for determination of total water-soluble, aliphatic aldehydes by means of the MBTH procedure,[39] during the fall using the mobile laboratory in North Charleston. Aldehydes were measured because of the types of emissions in the atmosphere from combustion and industrial sources and because certain aldehydes such as formaldehyde and acrolein appear to be important eye irritants.[13,40]

Results - Measured aldehyde concentrations ranged from 0.01 to 0.10 ppm, Table 4-60. The occurrence of relatively high concentrations, 0.06 ppm was related to wind speed and direction, Table 4-61. These data show that high concentrations occurred mainly when the wind speed was relatively high (for the Kanawha Valley) and the wind was from the southwesterly quadrant. From the wind direction data, the conclusion may be reached that the major sources of aldehyde emission affecting North Charles-

Table 4-60. TOTAL ALIPHATIC ALDEHYDE MEASUREMENTS IN NORTH CHARLESTON (ppm)

Date, 1965	Time[a]	Aliphatic aldehydes, as HCHO	Date, 1965	Time[a]	Aliphatic aldehydes, as HCHO
Oct. 28	1030	0.04	Nov. 5	0830	0.04
	1330	0.01		1030	0.03
	1530	0.01		1330	0.04
Oct. 29	0830	0.04		1530	0.03
	1030	0.02	Nov. 6	0830	0.04
	1330	0.03		1030	0.05
	1530	0.01		1330	0.03
Oct. 30	0830	0.05		1530	0.02
	1030	0.09	Nov. 8	0830	0.04
	1330	0.04		1030	0.01
	1530	0.03		1330	0.03
Nov. 1	0830	0.06		1530	0.04
	1030	0.08	Nov. 9	0830	0.03
	1530	0.02		1030	0.03
Nov. 2	0830	0.04		1330	0.01
	1030	0.04	Nov. 12	1530	0.07
	1330	0.04	Nov. 13	0830	0.05
	1530	-		1030	0.04
Nov. 3	0830	0.05		1330	0.04
	1030	0.04		1530	0.03
	1330	0.02	Nov. 15	1230	0.08
	1530	0.07	Nov. 16	0900	0.07
Nov. 4	0830	0.05		1030	0.07
	1330	0.02		1330	0.10
	1530	0.01		1530	0.07
			Nov. 17	1130	0.05
			Arithmetic mean		0.04

[a] 30-minute samples beginning at time indicated.

Table 4-61. RELATIONSHIP OF ALIPHATIC ALDEHYDE CONCENTRATIONS GREATER THAN 0.06 ppm, WIND SPEED AND DIRECTION IN NORTH CHARLESTON

Date, 1965	Time	Aldehydes, ppm	Wind speed, mph	Wind direction, angular degrees
Oct. 30	1030	0.09	8.5	250
Nov. 1	1030	0.08	7.5	270
Nov. 3	1530	0.07	6.5	235
Nov. 12	1530	0.07	7.0	150
Nov. 15	1230	0.08	8.0	240
Nov. 16	0900	0.07	10.0	225
Nov. 16	1030	0.07	9.0	230
Nov. 16	1330	0.10	4.5	220
Nov. 16	1530	0.07	7.0	235

ton lie to the southwest. From the high wind speed associated with these measurements, the conclusion may also be reached that the high aldehyde concentrations result from direct transport from sources to receptor.

Table 4-62 is a summary of aldehyde measurements made during the 1950-1951 Air Pollution Study. A comparison of the 1950-1951 data with data obtained during the present study indicates that the average aldehyde concentration in the ambient air has remained relatively constant. The maximum concentration reported for the North Charleston area during the 1950-1951 study (0.172 ppm) is approximately twice that recorded in the same area during the 1964-1965 study (0.10 ppm). The maximum value reported in the 1950-1951 study was measured at St. Albans (0.378 ppm) and is approximately 4 times that found in the North Charleston area in the 1964-1965 study.

STUDENT ODOR SURVEYS

General

Two odor surveys were made using students from 13 high schools to define the geographic distribution, intensity, duration, and type of odor occurrences. The first survey was conducted during the fall of 1964, November 2 through 22, and the second during the spring of 1965, April 25 through May 13. The locations of the various high schools in the study area are shown in Figure 4-51.

The students were principally sophomores, with students from other classes used in order to fully cover geographical areas of interest. The student observ-

Table 4-62. SUMMARY OF ALDEHYDE CONCENTRATIONS REPORTED IN 1950-1951
KANAWHA VALLEY AIR POLLUTION STUDY
(ppm, HCHO)

Station	State Health Department						Kettering Institute		
	8 a.m. to 4 p.m.			4 p.m. to 10 a.m.					
	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum
Charleston	0.047	0.228	0.000	0.048	0.169	0.000	0.046	0.130	0.025
South Charleston	0.044	0.172	0.000	0.034	0.122	0.000	0.033	0.076	0.000
North Charleston	0.041	0.172	0.000	0.025	0.097		0.040	0.130	0.013
Kanawha City	0.048	0.227	0.000	0.029	0.101	0.000	0.031	0.057	0.009
St. Albans	0.058	0.378	0.000	0.039	0.191	0.000	0.036	0.120	0.009
Institute	0.053	0.104	0.000						
Belle				0.024	0.102	0.000	0.041	0.067	0.025

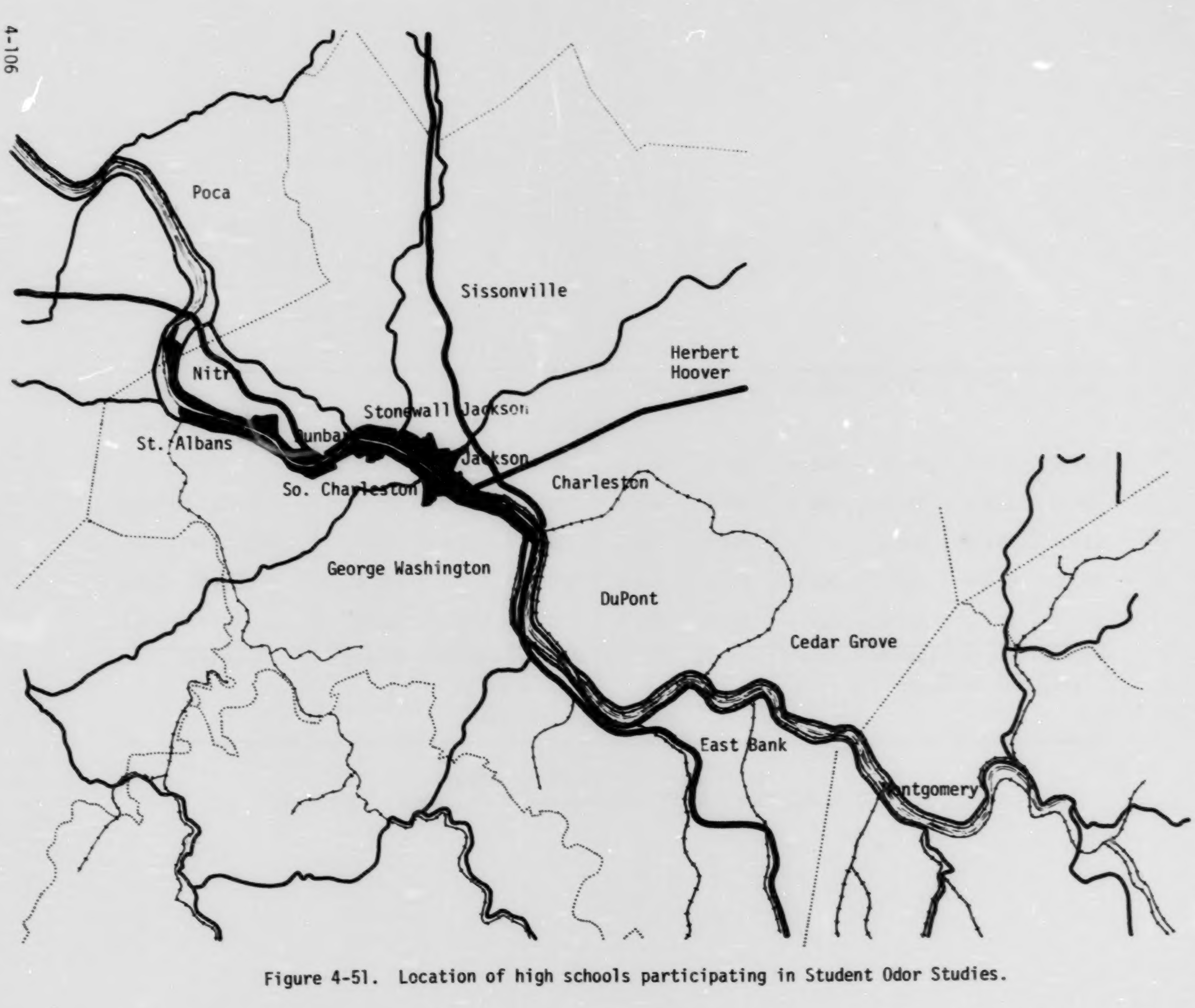

Poca
Sissonville
Herbert Hoover
Nitr
Stonewall Jackson
Dunba
St. Albans
Jackson
So. Charleston
Charleston
George Washington
DuPont
Cedar Grove
East Bank
ntgomery

Figure 4-51. Location of high schools participating in Student Odor Studies.

ers were selected by participating teachers or principals with some assistance by the study staff. The criteria for the selection of students were conscientiousness, odor acuity, and the geographical location of the student's residence.

The study staff met with the participating students at each school prior to the odor survey and conducted an orientation session. All phases of the Kanawha Valley Air Pollution Study were briefly discussed. This was followed by an explanation of the odor survey, including objectives, the forms and methods to be used, description of the odor test, and a question and answer period. The students were then tested for odor sensitivity to insure that they were capable of detecting odors.[41-43] A brief description of the odor sensitivity test can be found in Appendix D.

The student observation sheets were collected both during and at the end of the surveys, and were either mailed to the Air Pollution Control Commission or were collected from the participating teachers by members of the study staff. Due to the closing of schools for summer vacation in May 1965, some difficulty was experienced in obtaining the completed observation sheets from a few students. A follow-up made during the fall of 1965 school term to obtain the missing questionnaires was not successful.

The positive odor responses from student observations were divided, according to the students descriptions of the odor, into eight classifications (Table 4-63). Due to the complexity of the sources of the odorous pollutant emissions, the variety and number of the emissions, and the limited training of the student observers, the observed odors as recorded by the students were very difficult to classify. For example, the description "dead fish" could indicate the presence of amines, an organic chemical manufactured and used by several of the valley's chemical plants. Also, descriptions such as rotten cheese, oranges, etc. could easily describe emissions from chemical or industrial waste-treatment facilities located in several valley areas. Most of the odors listed in the miscellaneous classification are probably industrial chemicals, as many of these odors are combinations of several chemical compounds, with the combination having an odor unlike any of the contributing compounds and extremely difficult to describe, even by trained personnel. Several of the industrial complexes have odors which are specific for that area or for a particular process or plant. These odors, however, could not be described by the odor of a certain compound.

Table 4-63. CLASSIFICATION OF DESCRIPTIONS OF ODORS FOUND IN STUDENT ODOR SURVEYS
KANAWHA VALLEY AIR POLLUTION STUDY

Odor classifications		
Title	Descriptions of odors determined by the study staff to be present:	Examples
Chemical	Industrial chemical emissions	Chemical, bleach, rotten eggs, acid
Probable chemical	Industrial chemicals, but could possibly fit into another classification	Rotten, sour, bitter organic, salt
Decomposition (Possible chemical)	Decomposition of waste materials, but could possibly indicate industrial chemical odors	Sewage, dead fish, garbage
Food (Possible chemical)	Food or the cooking of food, could include industrial chemical odors	Popcorn, cooking meat, cooking bread
Combustion	Combustion from any source such as automobiles, wastes, leaves, etc.	Burning leaves, wood, trees, waste, automobile exhaust
Industrial	All industrial process odors with the exception of industrial chemical odors	Asphalt, creosote, wood, sawdust, dust, gasoline
Natural	Odors other than those caused by man and his activities	Flowers, trees, grass, fruit trees, earth
Miscellaneous	None of the above classifications; most odors listed in this class are probably industrial chemical	Colors, indescribable, no description

Fall 1964 Student Odor Survey

During the first student odor survey, November 2 through November 22, 1964, approximately 373 high school students participated as observers. Odor observations were made by these students at their homes at 0700, 1700, and 2000. The maximum number of possible observations was 23,499. The observers made 13,705 actual observations or 58.3 percent of the possible observations and made 8,398 positive observations or 35.7 percent of the possible (maximum) observations and 61.3 percent of the actual observations. The student participation was good during this first, or fall, study.

The results of the fall survey are presented by both school-area and time of observation. Tables 4-64 and -65 summarize the odor observations by school-area

Table 4-64. SUMMARY OF STUDENT ODOR OBSERVATIONS BY SCHOOL-AREA (NUMBER)
FALL 1964

School	Total observations	Positive observations	Chemical	Probably chemical	Decomposition	Food	Combustion	Industrial	Natural	Miscellaneous	No description
Poca	484	289	9	3	12	9	217	4	32	2	1
Nitro	1,155	628	31	33	10	12	459	13	36	13	21
St. Albans	1,520	925	103	44	25	15	618	30	69	7	14
Dunbar	1,612	943	164	43	24	12	590	19	47	9	35
Sissonville	1,200	706	87	26	7	46	462	11	45	2	20
South Charleston	961	549	48	27	12	13	366	10	40	18	15
Stonewall Jackson	839	580	65	18	9	14	379	3	56	5	31
George Washington	1,068	641	31	16	1	3	524	5	30	2	29
Charleston	866	558	16	8	22	0	467	4	36	2	3
DuPont	1,268	806	17	11	18	6	614	5	87	15	33
Cedar Grove	1,134	781	12	30	25	18	561	50	72	1	12
East Bank	774	504	32	7	13	1	409	4	26	1	11
Montgomery	824	488	4	10	30	5	368	9	54	0	8
Totals	13,705	8,398	619	276	208	154	6,034	167	630	77	233

Table 4-65. SUMMARY OF STUDENT ODOR OBSERVATIONS BY SCHOOL-AREA (PERCENT)
FALL 1964

School	Chemical	Probably chemical	Decomposition	Food	Combustion	Industrial	Natural	Miscellaneous	No description
Poca	3	1	4	3	75	1	11	1	1
Nitro	5	5	2	2	73	2	6	2	3
St. Albans	11	5	3	2	67	3	7	1	2
Dunbar	17	5	3	1	63	2	5	1	4
Sissonville	12	4	1	7	65	2	6	1	3
South Charleston	9	5	2	2	67	2	7	3	3
Stonewall Jackson	11	3	2	2	65	1	10	1	5
George Washington	5	2	1	1	82	1	5	1	5
Charleston	3	1	4	0	84	1	6	1	1
DuPont	2	1	2	1	76	1	11	2	4
Cedar Grove	2	4	3	2	72	6	9	1	2
East Bank	6	1	3	1	81	1	5	1	2
Montgomery	1	2	6	1	75	2	11	0	2

and indicate by number of observations and, by percentages, the breakdown of odors by classifications. The largest and most significant classification was combustion, with 6,034 observations or 72 percent of the positive observations. These results are indicative of the serious forest fire and meteorological conditions which were present in Southern West Virginia during the fall of 1964. Students from Charleston High School reported the highest percentage of odor classed as combustion while students from Dunbar reported the lowest percentage. Natural odors were the second highest classification reported with 8 percent of the positive observations followed closely by those odors classed as chemical (7 percent). The other classifications were small (3 percent or less) when compared with the combustion classification, and are less than half the observations classed as natural or chemical. The natural odors were more prevalent in the Montgomery and Poca areas (11 percent), with Dunbar, George Washington, and East Bank reporting the smallest percentage (5 percent). Schools reporting 10 percent or higher chemical odors were Dunbar (11 percent), Sissonville (12 percent), St. Albans (11 percent), and Stonewall Jackson (11 percent), with students from Montgomery High School reporting the lowest percentage of odors classed as chemical. Dunbar had the highest number of observations classified as chemical (164), followed by St. Albans (103), Sissonville (87), Stonewall Jackson (65), and South Charleston (48). School-areas reporting a significant percentage of probable chemical odors (5 percent or greater) were Nitro, St. Albans, Dunbar, and South Charleston. Both the chemical and probable chemical odors were concentrated at schools located near chemical complexes. The observations reported as chemical were lower than expected for the Poca, Nitro, South Charleston, and the schools near the Belle complex, DuPont, Cedar Grove, East Bank, and Charleston. This could be due to odors from the forest fires, which were high for these school-areas, masking the chemical odors.

The variation of odors as a function of time during the day is presented in Table 4-66. This table indicates little variation in observed odors for all classes except for combustion and natural odors. The natural odors were more prevalent in the morning (10 percent), and decreased in the evening (6 percent at 1700, 7 percent at 2000). Odors classified as combustion increased during the day from 68 percent in the morning to 74 percent at night. This may indicate increased burning during the evening hours due to regulations restricting open burning to the hours of 1700 through 0500 for the fall (October to December) and spring (March through May) seasons.

Spring 1965 Student Odor Survey

The second student odor survey was conducted during the spring of 1965, from April 23 through May 13. The students again made odor observations at home,

Table 4-66. SUMMARY OF STUDENT OBSERVATIONS AS A FUNCTION OF TIME
FALL 1964

	Total observations	Positive observations	Chemical		Probably chemical		Decomposition		Food		Combustion		Industrial		Natural		Miscellaneous		No Description
Observation time	Number	Number	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	Percent
0700	4,592	2,873	232	8	123	4	56	2	49	2	1,960	68	44	2	287	10	33	1	3
1700	4,671	2,841	194	7	77	3	85	3	66	2	2,082	73	67	2	168	6	27	1	3
2000	4,442	2,684	193	7	76	3	67	2	39	1	1,992	74	56	2	175	7	17	1	3
Average				7		3		2		2		72		2		7		1	3
Total	13,705	8,390	619		276		208		154		6,034		167		630		77		

at 0700, 1700, and 2000. The number of students participating changed from 373 to 383 for a possible total of 24,129 odor observations. The students made 10,845 actual observations or 44.9 percent of the total possible observations and made 3,300 positive observations or 13.7 percent of the possible observations and 30.4 percent of the actual observations. Students at Sissonville had the highest percentage of actual observations (81.2), with Cedar Grove second (74.5 percent), and Nitro third (68.7 percent). Montgomery High School had the lowest percentage of observations (14.9 percent). Unfortunately, this was due to a misunderstanding causing the students to begin several days after the April 23rd starting date.

Mention should be made of the fact that another orientation session with a review of the procedures was not conducted. The observation results would seem to indicate that this should be done in future studies. Also, the maintenance of close contact with the student observers, plus a rapid review of the completed observation sheets and feed back of necessary information to the students participating in the survey should be incorporated in similar studies.

The results of the spring survey are presented on a school-area basis in Tables 4-67 and -68. Natural odors were the largest classification found during the spring survey with 1,143 observations (34.6 percent), followed by chemical (587 observations - 17.8 percent), and combustion (547 observations - 16.6 percent). The school-areas reporting significant numbers of natural odors were either suburban or rural, such as George Washington (164 observations - 72 percent), Cedar Grove (251 observations - 53 percent), and East Bank (105 observations - 45 percent). Schools such as Sissonville (81 observations - 27 percent) and Poca (14 observations - 36 percent) are both suburban or rural and would be expected to have a higher percentage of natural odors. This relatively small percentage of natural odors is probably due to the close proximity of large chemical complexes and also meteorological factors which tend to transport odorous compounds emitted in the valley to the school-areas. The second highest odor classification (chemical) was reported principally by the lower valley school-areas. Schools reporting 20 percent or higher were Poca (10 observations - 26 percent), Dunbar (115 observations - 36 percent), Sissonville (61 observations - 21 percent), South Charleston (41 observations - 26 percent), Stonewall Jackson (130 observations - 30 percent), and Charleston (55 observations - 27 percent). George Washington High School, whose students are located either on the hills above or in rural or suburban areas away from the valley, reported that only 4 percent of the observations were either chemical or probable chemical. Of the schools located near the Belle complex, only Charleston reported significant chemical odors (27 percent), while student observations from DuPont (24 observations - 8 percent), East Bank (18 observations - 8

Table 4-67. SUMMARY OF ODOR OBSERVATIONS BY SCHOOL-AREAS (NUMBER)
SPRING 1965

Schools	Total observations	Positive observations	Chemical	Probable chemical	Decomposition	Food	Combustion	Industrial	Natural	Miscellaneous
Poca	231	39	10	3	1	5	5	1	14	0
Nitro	1,428	302	66	39	26	6	41	17	91	1
St. Albans	907	157	53	17	22	5	15	6	28	3
Dunbar	855	316	115	35	11	8	44	5	82	10
Sissonville	1,126	295	61	26	20	15	67	15	81	2
South Charleston	688	160	41	13	4	0	15	4	45	6
Stonewall Jackson	1,019	434	130	48	16	14	35	11	99	8
George Washington	930	228	8	9	2	1	26	18	164	0
Charleston	824	205	55	10	26	0	34	5	54	1
DuPont	1,024	314	24	15	56	7	82	15	87	1
Cedar Grove	986	473	5	16	42	34	83	35	251	3
East Bank	486	232	18	15	10	17	50	11	105	1
Montgomery	291	145	1	3	20	3	50	20	42	1
Totals	10,845	3,300	587	249	256	115	547	163	1,143	37

Table 4-68. SUMMARY OF STUDENT ODOR OBSERVATION BY SCHOOL-AREAS (PERCENT)
SPRING 1965

Schools	Chemical	Probable chemical	Decomposition	Food	Combustion	Industrial	Natural	Miscellaneous	No Description
Poca	26	8	2	13	13	21	36	0	0
Nitro	22	13	9	2	14	6	30	0	4
St. Albans	34	11	14	3	10	4	18	2	4
Dunbar	36	11	3	3	14	2	26	3	2
Sissonville	21	9	7	5	23	5	27	1	2
South Charleston	26	8	3	0	9	3	28	4	19
Stonewall Jackson	30	11	4	3	8	3	23	2	16
George Washington	4	4	1	1	11	8	72	0	0
Charleston	27	5	13	0	17	2	26	1	9
Cedar Grove	1	3	10	7	18	7	53	0	1
East Bank	8	6	4	7	22	5	45	1	2
Montgomery	1	2	14	2	34	14	29	1	3
DuPont	8	5	18	2	26	5	28	1	7

percent), and Cedar Grove (5 observations - 1 percent), were less than 10 percent.

Mention should be made of the fact that, with the exception of East Bank (10 observations - 4 percent), the schools near the Belle complex all have a high percentage of decomposition odors, DuPont (56 observations - 18 percent), Cedar Grove (42 observations - 10 percent), and Charleston (26 observations - 13 percent). Included in the decomposition classification are fishy-type odors which are a common description of the odor of amines, thus a number of these observations could and probably do represent odors caused by the industrial chemical complex. Amines are made and used in other areas of the valley and these characteristic odors are probably included in this classification at other schools. Combustion odors are reported to be high for areas where the open burning of refuse is common, i.e., rural and suburban areas. Odors from the incomplete combustion of gasoline and diesel fuel in automobiles, trucks, and railroad engines are also significant.

The food, industrial, and miscellaneous classifications were low for all school-areas with the exception of Poca (food - 13 percent) and Montgomery (industrial - 14 percent). Odors with no description were unusually high for South Charleston and Stonewall Jackson with 19 and 16 percent, respectively. This percentage was much higher than the other participating schools, whose reported percentages for this classification ranged from 9 percent at Charleston to 0 percent at both Poca and George Washington. This wide variation in observations may have been due to the students inability to describe some of the odors.

The comparison of odors with observation time is presented in Table 4-69. As was the case in the first survey, there seems to be little variation of observed odors with time, at least for the three periods studied. Also, the same pattern was observed for the natural and combustion odors, i.e., the natural odors were more prevalent in the morning hours than late afternoon or evening (0700-39 percent, 1700-33 percent, 2000-31 percent) while the opposite was observed for the combustion odors (0700-11 percent, 1700-17 percent, 2000-22 percent). This may be caused by increased burning and other activity late in the day due to forestry regulations.

The students were asked to indicate whether a particular odor was pleasant, unpleasant or no reaction. The results are presented in Table 4-70, and in Figures 4-52, -53, and -54.

Table 4-71 is a breakdown by school-area of the students' reactions to all observed odors. The percentage of unpleasant reactions ranged from a high of 63 percent at Montgomery to a low of 20 percent at George Washington. The schools

Table 4-69. SUMMARY OF STUDENT OBSERVATIONS AS A FUNCTION OF TIME SPRING 1965

	Total observations	Positive observations	Chemical		Probably chemical		Decomposition		Food		Combustion		Industrial		Natural		Miscellaneous		No Description
Observation time	Number	Number	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	Percent
0700	3,670	1,125	212	19	102	9	80	7	45	4	120	11	37	3	443	39	20	2	-
1700	3,642	1,143	192	17	79	7	99	9	43	4	198	17	76	7	382	33	6	1	5
2000	3,483	1,032	183	18	68	7	77	7	27	3	229	22	50	5	318	31	11	1	6
Average				18		8		8		3		17		5		35		1	5
Totals	10,795	3,300	587		249		256		115		547		163		1,143		37		

Table 4-70. STUDENT REACTIONS TO OBSERVED ODORS BY CLASSIFICATION

SPRING 1965

	None		Pleasant		Unpleasant		
Odor classification	Obser-vations	Percent	Obser-vations	Percent	Obser-vations	Percent	Total observations
Chemical	66	11	54	9	468	80	588
Probable chemical	28	12	39	16	176	72	243
Decomposition (Possibly chemical)	16	6	11	4	230	90	257
Food (Possibly chemical)	11	9	68	55	44	36	123
Combustion	71	14	35	7	403	79	509
Industrial	23	15	32	21	98	64	153
Natural	189	14	982	77	121	9	1,292
Miscellaneous	9	25	11	31	16	44	36
Total	413	13	1,232	38	1,556	49	3,201

in the lower valley reported unpleasant reaction at least 50 percent of the time. George Washington had the highest percentage of pleasant reactions and Nitro the lowest, 18 percent. Students from DuPont reported the greatest percentage of no reaction, followed closely by Poca with 21 percent, and Nitro with 20 percent. The reason for this lack of reaction to odors in these areas is not known.

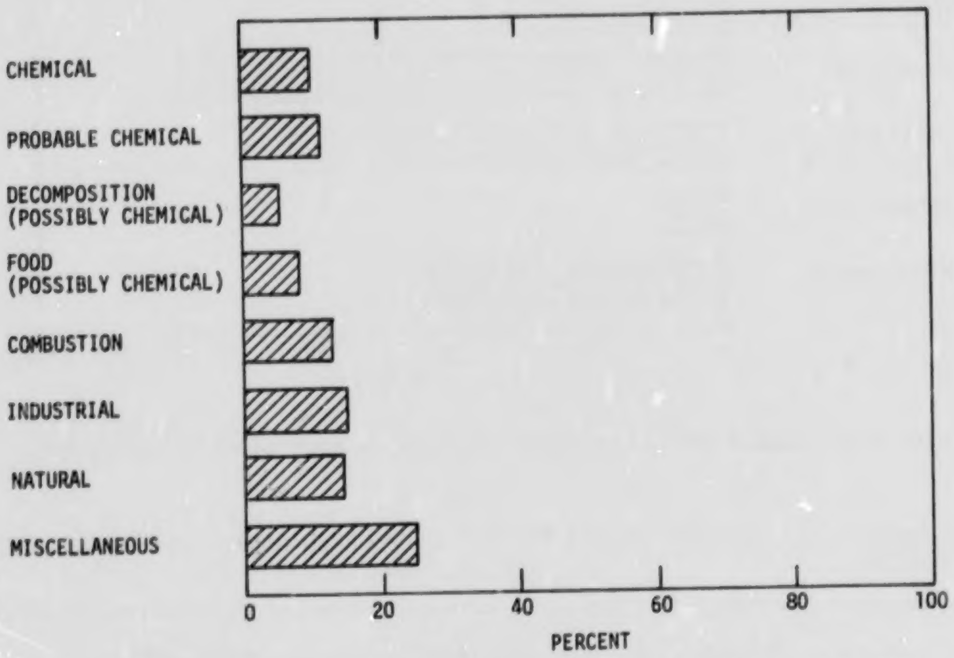


Figure 4-52. Student survey, no reaction to observed odors, spring 1965.

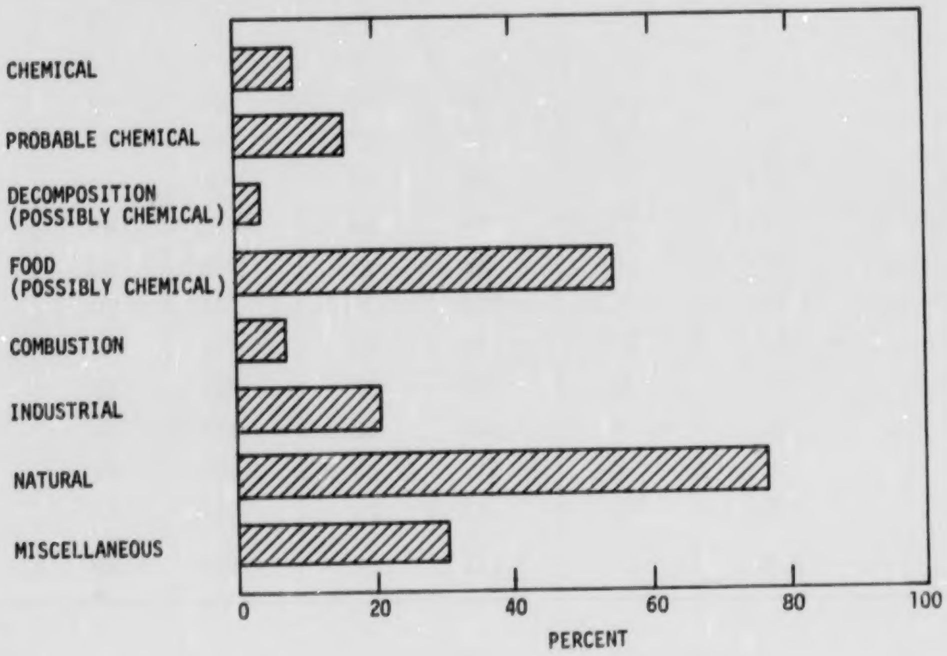


Figure 4-53. Student survey, pleasant reactions to observed odors, spring 1965.

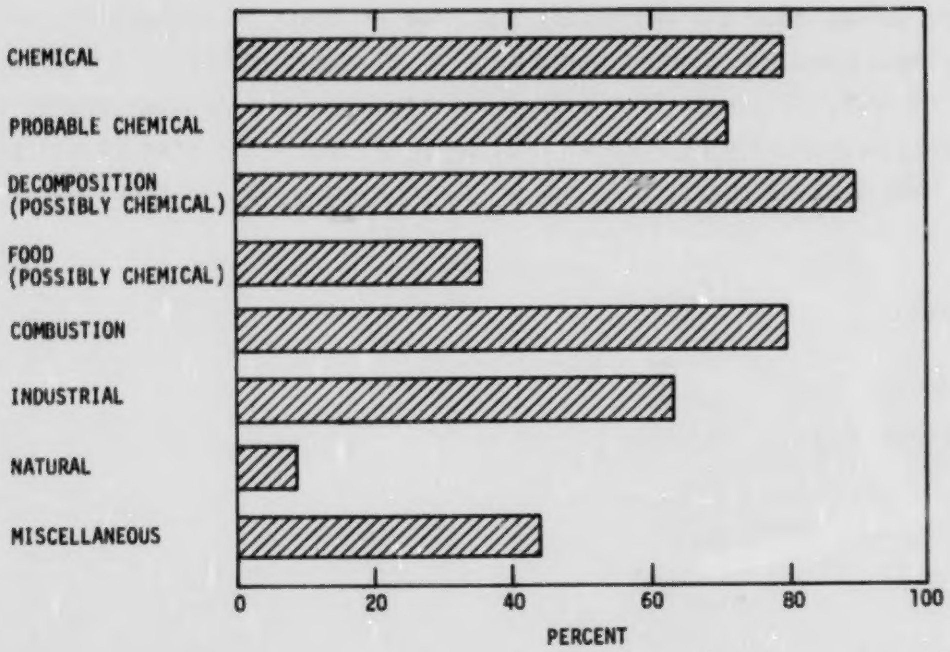


Figure 4-54. Student survey, unpleasant reactions to observed odors, spring 1965.

Table 4-71. STUDENT REACTIONS TO ALL OBSERVED ODORS - BY SCHOOL-AREA SPRING 1965

	No reaction		Pleasant		Unpleasant		
School	Observations	Percent	Observations	Percent	Observations	Percent	Total observations
Poca	8	21	10	26	20	53	38
Nitro	41	20	37	18	128	62	206
St. Albans	18	12	45	29	90	59	153
Dunbar	53	17	71	22	192	61	316
Sissonville	40	13	84	27	190	60	314
South Charleston	16	13	49	39	60	48	125
Stonewall Jackson	30	8	118	33	216	59	364
George Washington	13	6	167	74	44	20	224
Charleston	26	14	55	29	109	57	190
DuPont	73	22	103	32	150	46	326
Cedar Grove	60	11	338	62	148	27	546
East Bank	16	7	113	48	105	45	234
Montgomery	19	12	42	25	104	63	165
Total	413	13	1,232	38	1,556	49	3,201

To determine the effect of man-made odors on the students' senses, the odors classed as natural were deleted and the student reactions to all other observed odors are presented in Table 4-72. The percentage of the unpleasant reactions is increased at all school-areas, from 29 to 75 percent with the results ranging from a high of 86 percent at Montgomery to 61 percent at George Washington and Cedar Grove. The percentage of pleasant reactions sharply decreased, from 38 to 13 percent, with the results ranging from 24 percent at Cedar Grove to 3 percent at Nitro. The percentage of no reaction to odors remained relatively constant, decreasing from only 13 to 12 percent with the percentages for the individual schools changing. The reaction of the student observers to what would be considered man-made odors is that 75 percent of the observed odors are unpleasant. This definitely showed a need to control these type of odors in the Kanawha Valley.

Table 4-72. STUDENT REACTIONS TO OBSERVED ODORS EXCLUDING THE
NATURAL ODOR CLASSIFICATION
SPRING 1965

	No reaction		Pleasant		Unpleasant		
School	Observations	Percent	Observations	Percent	Observations	Percent	Total observations
Poca	4	17	1	4	19	79	24
Nitro	22	15	4	3	119	82	145
St. Albans	17	14	18	15	88	71	123
Dunbar	40	17	21	9	172	74	233
Sissonville	19	9	24	11	176	80	219
South Charleston	12	15	13	17	54	68	79
Stonewall Jackson	18	7	41	15	207	78	266
George Washington	10	17	13	22	36	61	59
Charleston	17	12	15	11	105	77	137
DuPont	13	7	22	13	142	80	177
Cedar Grove	32	15	54	24	136	61	222
East Bank	11	9	18	15	94	76	123
Montgomery	9	9	6	6	87	85	102
Totals	224	12	250	13	1,435	75	1,909

Odor Patrols

Odor patrols were conducted by the study staff to supplement the student odor surveys. These patrols were made on a routine and episode basis to determine the distribution, intensity, duration, and type of odor occurrences and also to attempt to pinpoint odor sources. These patrols were initiated in the spring of 1966 and were continued on an intermittent basis.

The methods used by the study staff in conducting these odor patrols were similar to those described by Gruber,[44] et al, Huey,[45] et al, and were used by the Abatement Branch, Division of Air Pollution, U. S. Public Health Service. The observer drove through the area to be patrolled with the car window open until a faint odor was detected. The observer would then use a scentometer (described in previously mentioned reports) to determine the odor strengths. Helium filled balloons and a compass were used to indicate the direction of the odor source. The point was located on a map and the odor strength, direction of wind, description of odor, time, and date were recorded. These observations were continued until the intensity and distribution of the odor observed was determined. If additional (different) odors were observed, the same procedure was used.

Odor strength has been expressed objectively in terms of odor units, an odor unit being defined as 1 cu ft of air at the odor threshold.[45] Table 4-73 indicates the strength of an odor in terms of the number of dilutions to threshold with the corresponding diameter of the intake orifice used as the scentometer.

The study staff modified these methods of odor observation because of the unique conditions in the Kanawha Valley. A two-man team was used to obtain concurrent measurement of odor strength and both wind speed and direction. One team member used a hand-held wind instrument while the other made the odor observation. Considerable difficulty was experienced during the earlier patrols in obtaining wind data and odor strength. Also, the two-man teams made regular and more frequent odor patrols.

Table 4-73. ODOR STRENGTH CHART FOR SCENTOMETER

Odor strength, odor units	Number of dilutions to threshold	Diameter of intake orifice, inches
1 (Maximum)	170	1/16
2	31	1/8
3	7	1/4
4	2	1/2
5 (Minimum or faint)	None	-

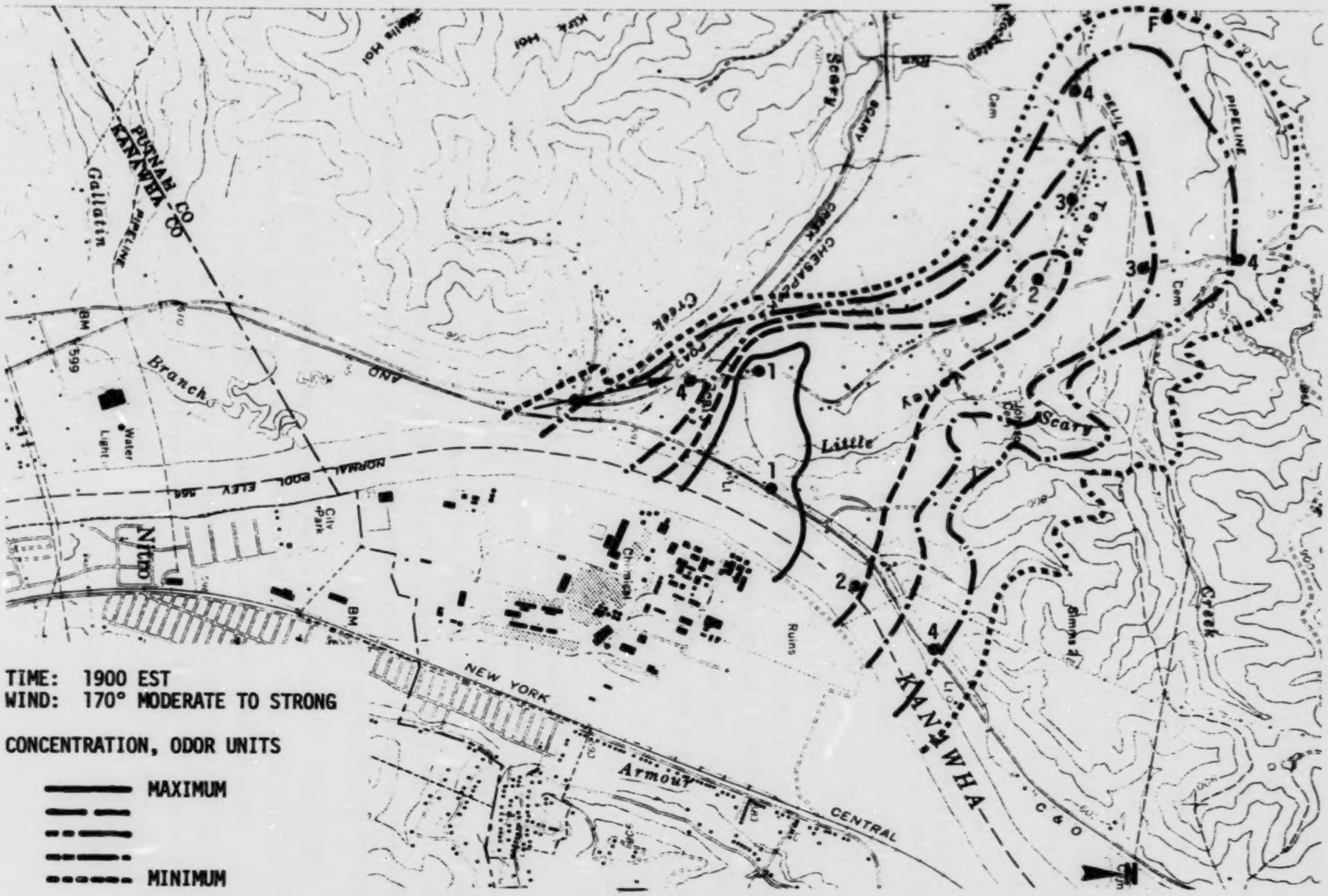
The odors most frequently observed and recorded in the Nitro area were those described as mercaptans and hydrogen sulfide. Figures 4-55 and -56 indicate the extent and variability of the distribution of these odors. The situation, as shown in Figure 4-56, can be the cause of considerable complaints. Limited odor patrols in the downriver area were not successful in obtaining useful data.

Information on a variety of odors was obtained in the area surrounding the South Charleston complex. The following Figures 4-57 through 4-67 indicate the distribution and strength of odors observed in the South and North Charleston areas. Figures 4-57 and -58 indicate the extent of odors described as sulfuric acid mist while Figures 4-59 and -60 show the extent of acetic acid emissions. An odor described as sweet is shown to occur in both North and South Charleston (Figures 4-61 and -62). Chemists, trained in odor observations, have difficulty in identifying some of the odors found in and around these chemical complexes. Hydrogen sulfide odors were observed and the extent of their effect is shown in Figures 4-63, -64, and -65. The results of these patrol observations would seem to pinpoint a potential hydrogen sulfide source near the mound in South Charleston. The extent of the effect of odors described as rotten are shown in Figures 4-66 and -67. The results in some circumstances, such as the possible source of the hydrogen sulfide emission, do indicate the location of an odor source. As can be seen from the other figures and from the results of this work, the pinpointing of many of the odor sources will require the frequent use of odor patrols.

Conclusions

The results from both the student odor survey and the odor patrols indicate that there is a significant problem with objectionable odors throughout the Kanawha Valley study area. The high percentage of odors described as objectionable by the student observers indicates many of the man-made odors are considered to be undesirable as well as a nuisance. The data also indicate that the odor problem is not confined to those areas surrounding the industrial chemical complexes, but affects the entire study area.

The results from the odor patrols provide an indication of the extent of the effect of a source of odorous emissions. This survey also indicated the difficulty experienced in pinpointing sources of odorous emissions in an industrial chemical complex with the problem compounded by the effects of valley meteorology and topography. These patrols also provide useful data on odors and help develop trained observers and patrol methods applicable to the Kanawha Valley.



TIME: 1900 EST
WIND: 170° MODERATE TO STRONG
CONCENTRATION, ODOR UNITS
MAXIMUM
MINIMUM
PUTNAM CO
KANAWHA CO
Gallatin
PIPELINE
BM 599
Water
Light
Branch
Nitro
City Park
NORMAL POOL ELEV 566
Chemical
Ruins
NEW YORK
CENTRAL
Armour
KANAWHA
C&O
Creek
Scary
SCARY CREEK
CHESAPEAKE
Little
Teays
Cem
Simms
1
2
3
4

Figure 4-55. Mercaptan and hydrogen sulfide odors found in the Nitro area, April 27, 1966.

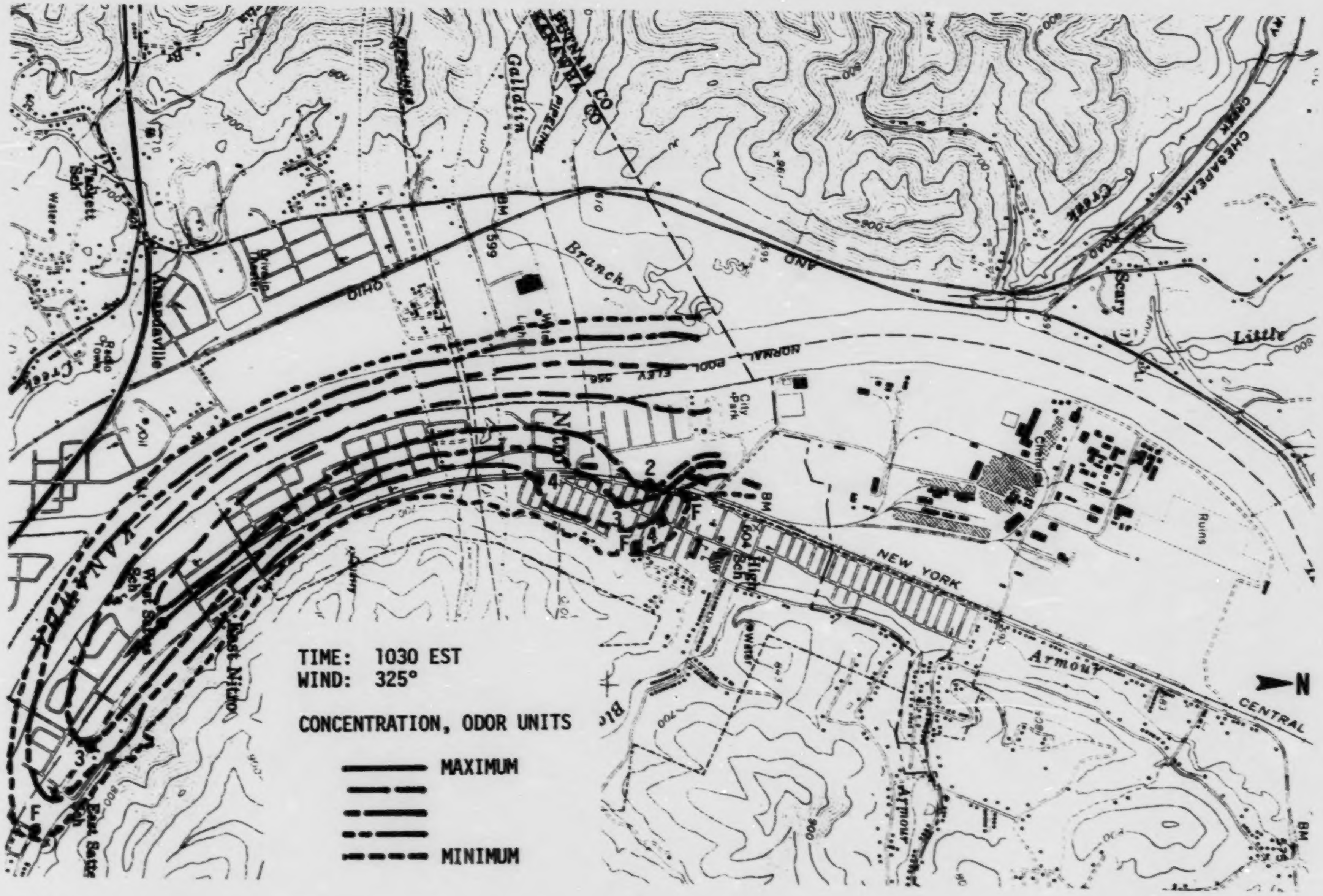

TIME: 1030 EST
WIND: 325°
CONCENTRATION, ODOR UNITS
MAXIMUM
MINIMUM
N
Scary
Little
CHESAPEAKE
AND
OHIO
Creek
Branch
Gallatin
PIPELINE
PUTNAM CO
KANAWHA CO
NORMAL POOL ELEV 566
City Park
Nitro
BM 599
BM 604
High Sch
NEW YORK
CENTRAL
Armour
Ruins
Chemical
Drive-in Theater
Amandaville
Tackett Sch
Radio Tower
Oil
KANAWHA
West Sattes Sch
East Nitro
East Sattes Sch
Quarry
Water
BM 575
F
2
3
4

Figure 4-56. Mercaptan and hydrogen sulfide odors found in the Nitro area, August 4, 1966.

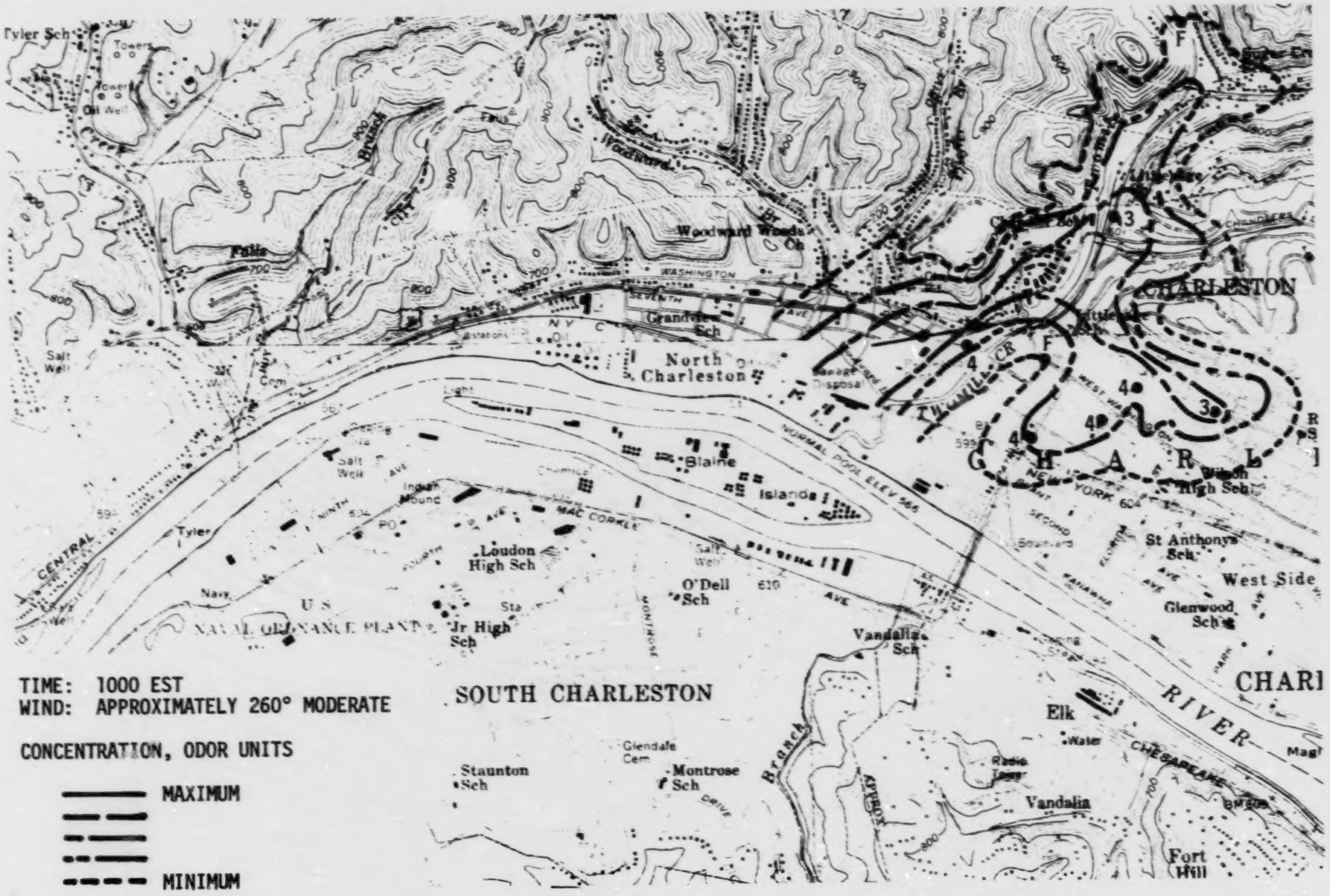

TIME: 1000 EST
WIND: APPROXIMATELY 260° MODERATE
CONCENTRATION, ODOR UNITS
MAXIMUM
MINIMUM
CHARLESTON
NORTH Charleston
SOUTH CHARLESTON
RIVER
Tyler Sch
Woodward Woods Ch
Grandview Sch
Blaine
Islands
Loudon High Sch
Jr High Sch
O'Dell Sch
Vandalia Sch
St Anthonys Sch
West Side
Glenwood Sch
Wilson High Sch
Staunton Sch
Montrose Sch
Glendale Cem
Elk
Vandalia
Fort Hill
U S NAVAL ORDNANCE PLANT
NORMAL POOL ELEV 566
Salt Well
Indian Mound
3
4

Figure 4-57. Acid mist (sulfuric) odors found in the North Charleston area, April 21, 1966.

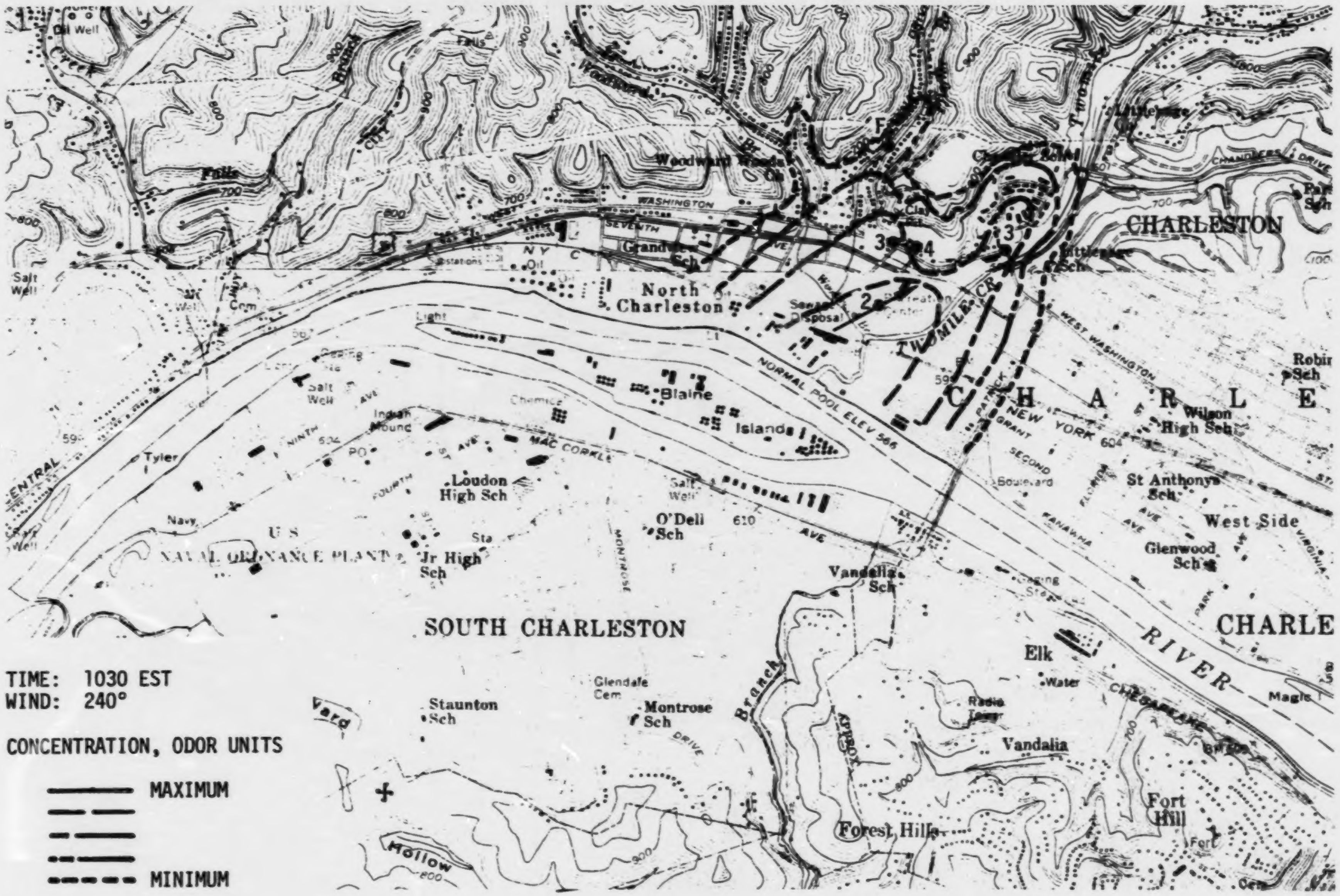

TIME: 1030 EST
WIND: 240°
CONCENTRATION, ODOR UNITS
MAXIMUM
MINIMUM
1
2
3
4
CHARLESTON
North Charleston
SOUTH CHARLESTON
CHARLE
RIVER
NORMAL POOL ELEV 566
Blaine
Islands
Loudon High Sch
O'Dell Sch
Jr High Sch
U S NAVAL ORDNANCE PLANT
Staunton Sch
Montrose Sch
Glendale Cem
Vandalia Sch
Vandalia
Forest Hills
Fort Hill
Elk
Wilson High Sch
St Anthonys Sch
West Side
Glenwood Sch
Grandview Sch
Woodward
WASHINGTON
WEST WASHINGTON
NEW YORK
SEVENTH
TWO MILE CR
MAC CORKLE
Tyler
Salt Well
Oil Well

Figure 4-58. Acid mist (sulfuric) odors found in the North Charleston area, August 2, 1966.

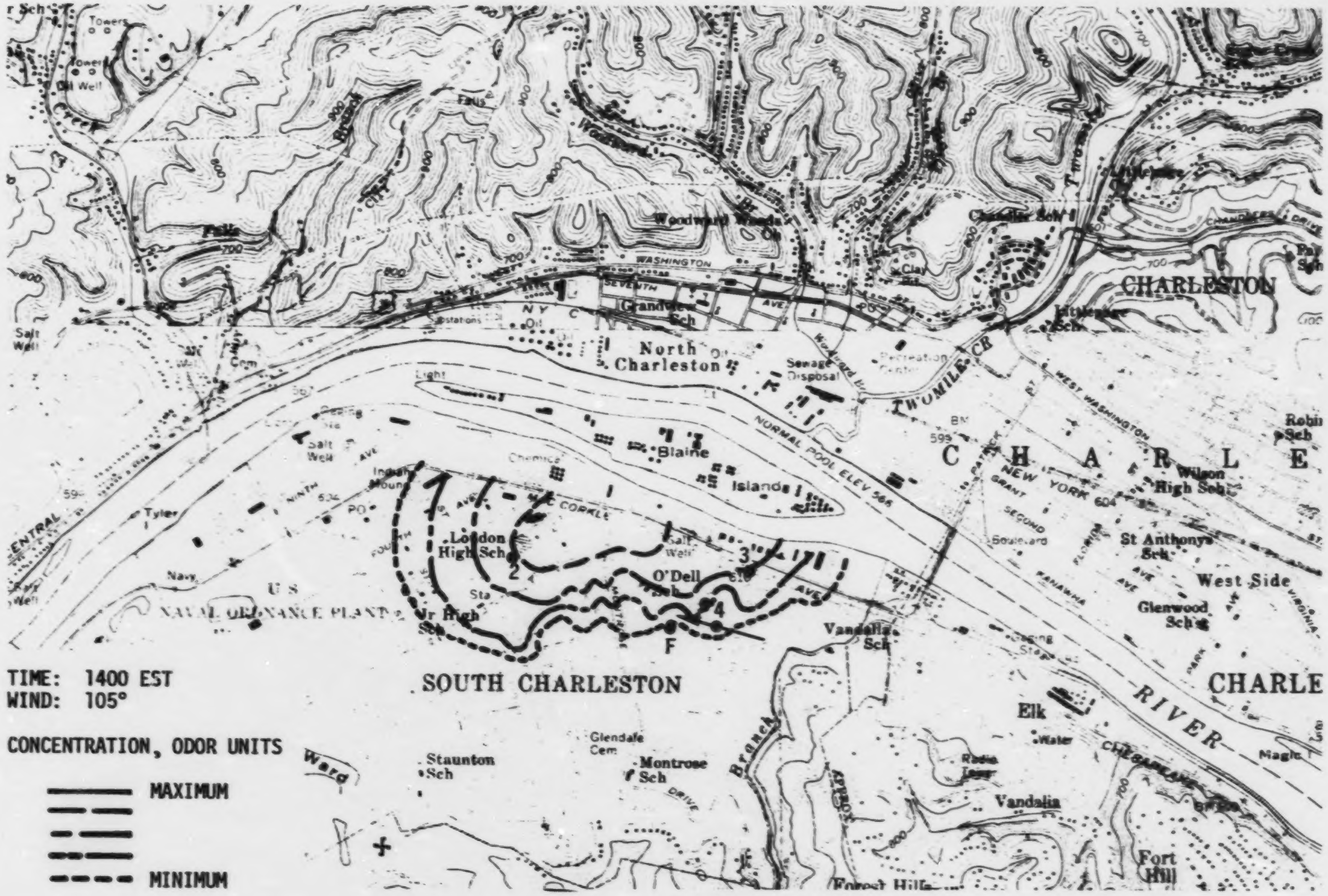

TIME: 1400 EST
WIND: 105°
CONCENTRATION, ODOR UNITS
MAXIMUM
MINIMUM
CHARLESTON
North Charleston
Grandview Sch
Woodward
Chandler Sch
Sewage Disposal
Recreation Center
TWOMILE CR
WEST WASHINGTON
WASHINGTON
Blaine
Islands
NORMAL POOL ELEV 566
C H A R L E
Wilson High Sch
NEW YORK
St Anthonys Sch
West Side
Glenwood Sch
London High Sch
O'Dell
2
3
4
F
U S NAVAL ORDNANCE PLANT
Jr High Sch
Vandalia Sch
SOUTH CHARLESTON
Glendale Cem
Staunton Sch
Montrose Sch
Ward
Branch
Elk
RIVER
CHARLE
Vandalia
Fort Hill
Forest Hills
Salt Well
Tyler
Navy

Figure 4-59. Acid mist (acetic) odors found in the South Charleston area, May 25, 1966.

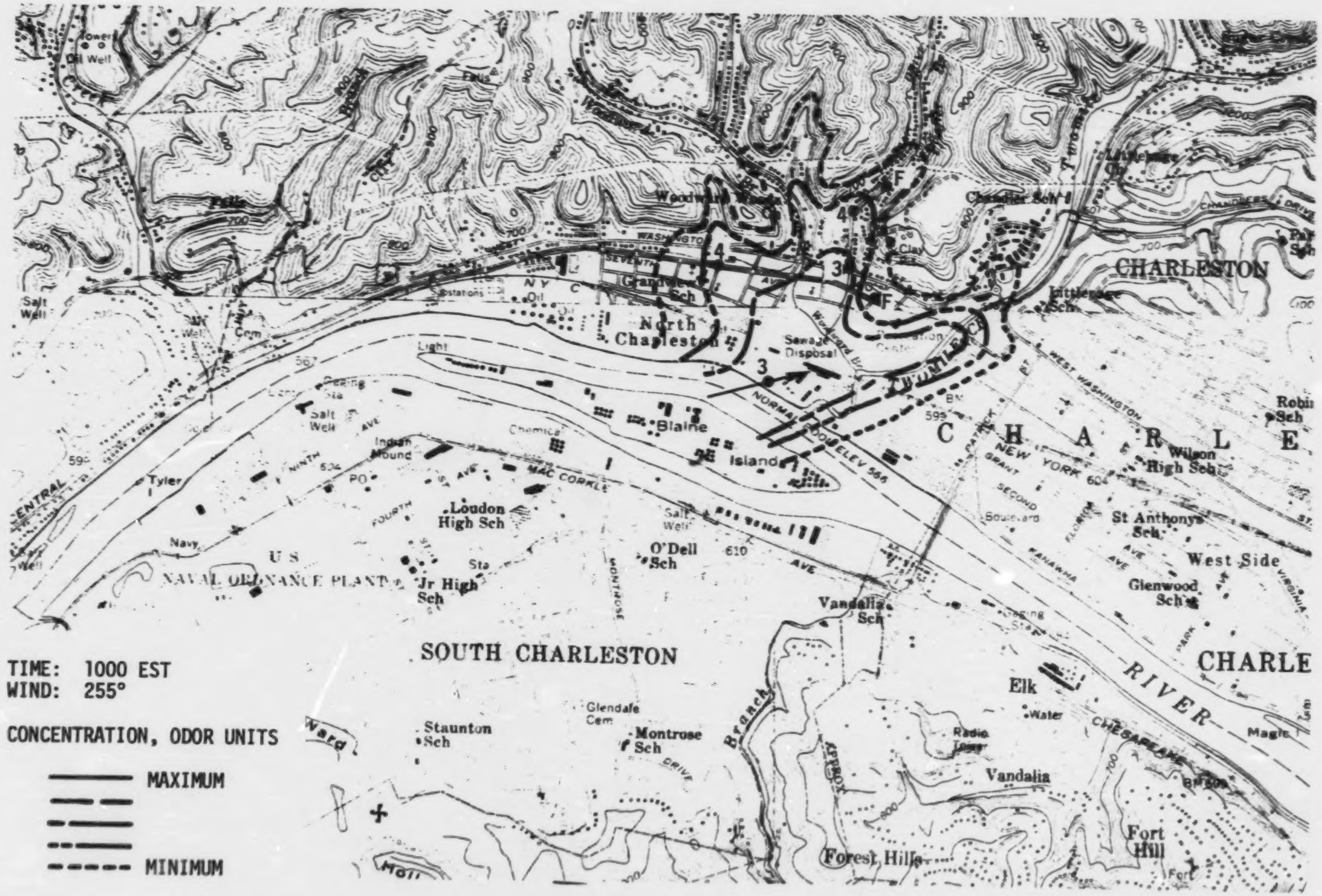

TIME: 1000 EST
WIND: 255°
CONCENTRATION, ODOR UNITS
MAXIMUM
MINIMUM
4
4
3
3
F
F
CHARLESTON
North Charleston
SOUTH CHARLESTON
C H A R L E
CHARLE
RIVER
Blaine
Island
Sewage Disposal
Grandview Sch
Woodward
Chandler Sch
Littlepage Sch
Wilson High Sch
St Anthonys Sch
West Side
Glenwood Sch
Vandalia Sch
Vandalia
Elk
Fort Hill
Forest Hills
Branch
Loudon High Sch
Jr High Sch
O'Dell Sch
Staunton Sch
Montrose Sch
Glendale Cem
US NAVAL ORDNANCE PLANT
Tyler
Navy
Salt Well
Indian Mound
Chemical
Light
WEST WASHINGTON
NEW YORK
KANAWHA
MAC CORKLE
MONTROSE
CHESAPEAKE
Oil Well
Falls
Creek
Radio Tower
Water
Magic
Ward
Robin Sch
ELEV 586
599
604
610
567
700
800
900

Figure 4-60. Acid mist (acetic) odors found in the North Charleston area, August 1, 1966.

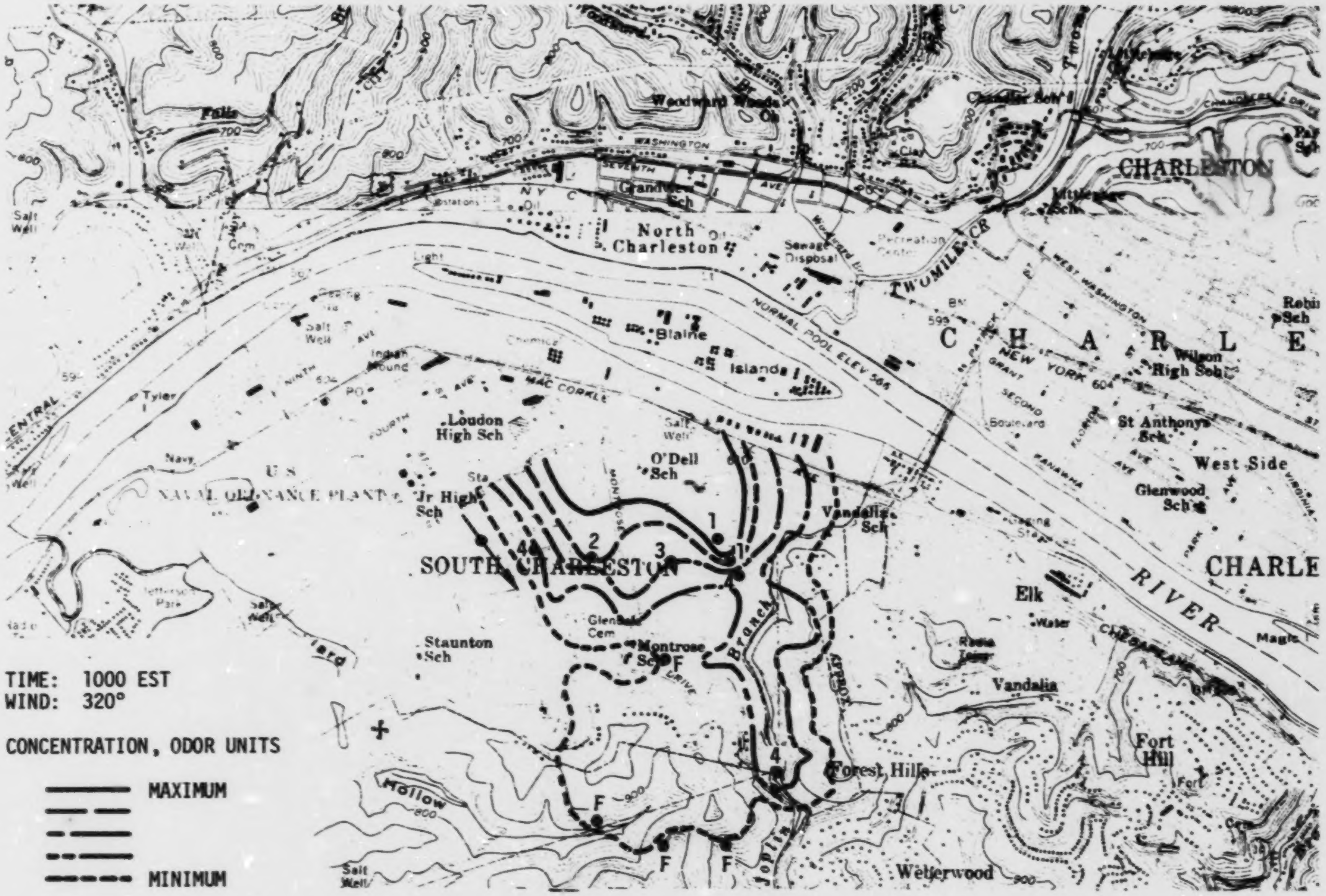

TIME: 1000 EST
WIND: 320°
CONCENTRATION, ODOR UNITS
MAXIMUM
MINIMUM
1
2
3
4
F
CHARLESTON
North Charleston
SOUTH CHARLESTON
RIVER
NORMAL POOL ELEV 566
Blaine
Islands
O'Dell Sch
Loudon High Sch
Jr High Sch
U S NAVAL ORDNANCE PLANT
Staunton Sch
Montrose Sch
Glenwood Sch
Vandalia Sch
Forest Hills
Vandalia
Fort Hill
Elk
West Side
St Anthonys Sch
Wilson High Sch
Grandview Sch
Sewage Disposal
Woodward Woods
Weberwood
Hollow
Salt Well
Tyler
Navy
Falls
C H A R L E

Figure 4-61. Odor described as sweet found in the South Charleston area, July 20, 1966.

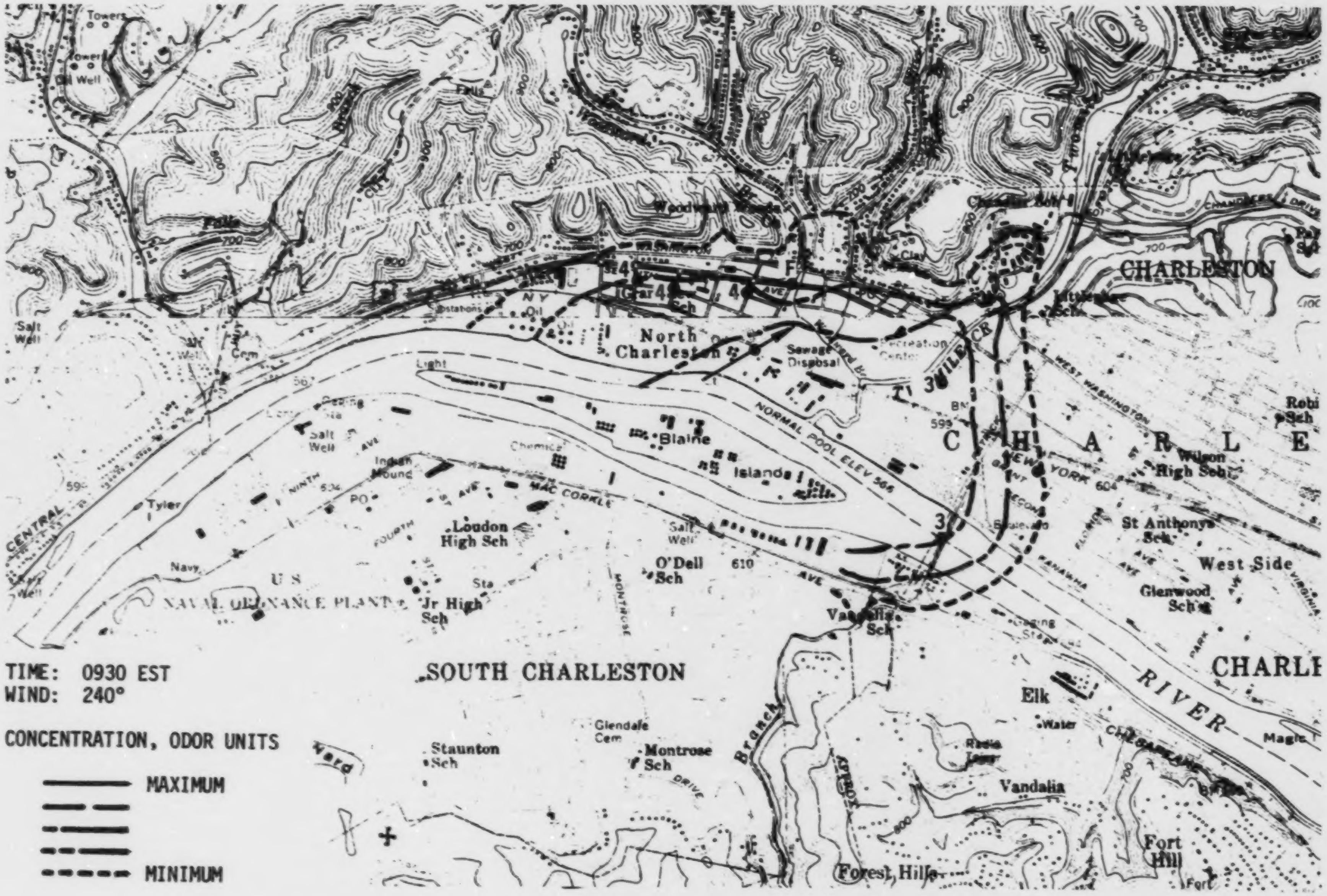

TIME: 0930 EST
WIND: 240°
CONCENTRATION, ODOR UNITS
MAXIMUM
MINIMUM
CHARLESTON
North Charleston
SOUTH CHARLESTON
CHARLE
CHARL
RIVER
Sewage Disposal
Recreation Center
Blaine
Islands
NORMAL POOL ELEV 566
WEST WASHINGTON
NEW YORK
Wilson High Sch
St Anthonys Sch
West Side
Glenwood Sch
Vandalia Sch
Vandalia
Elk
Fort Hill
Forest Hills
Loudon High Sch
O'Dell Sch
Jr High Sch
Staunton Sch
Montrose Sch
Glendale Cem
Salt Well
Indian Mound
U S
NAVAL ORDNANCE PLANT
Tyler
Navy
MAC CORKLE
Light
Chemical
Oil Well
Towers
Falls
Branch
Radio Tower
CHESAPEAKE
Robi Sch

Figure 4-62. Odor described as sweet found in the North Charleston area, August 2, 1966.

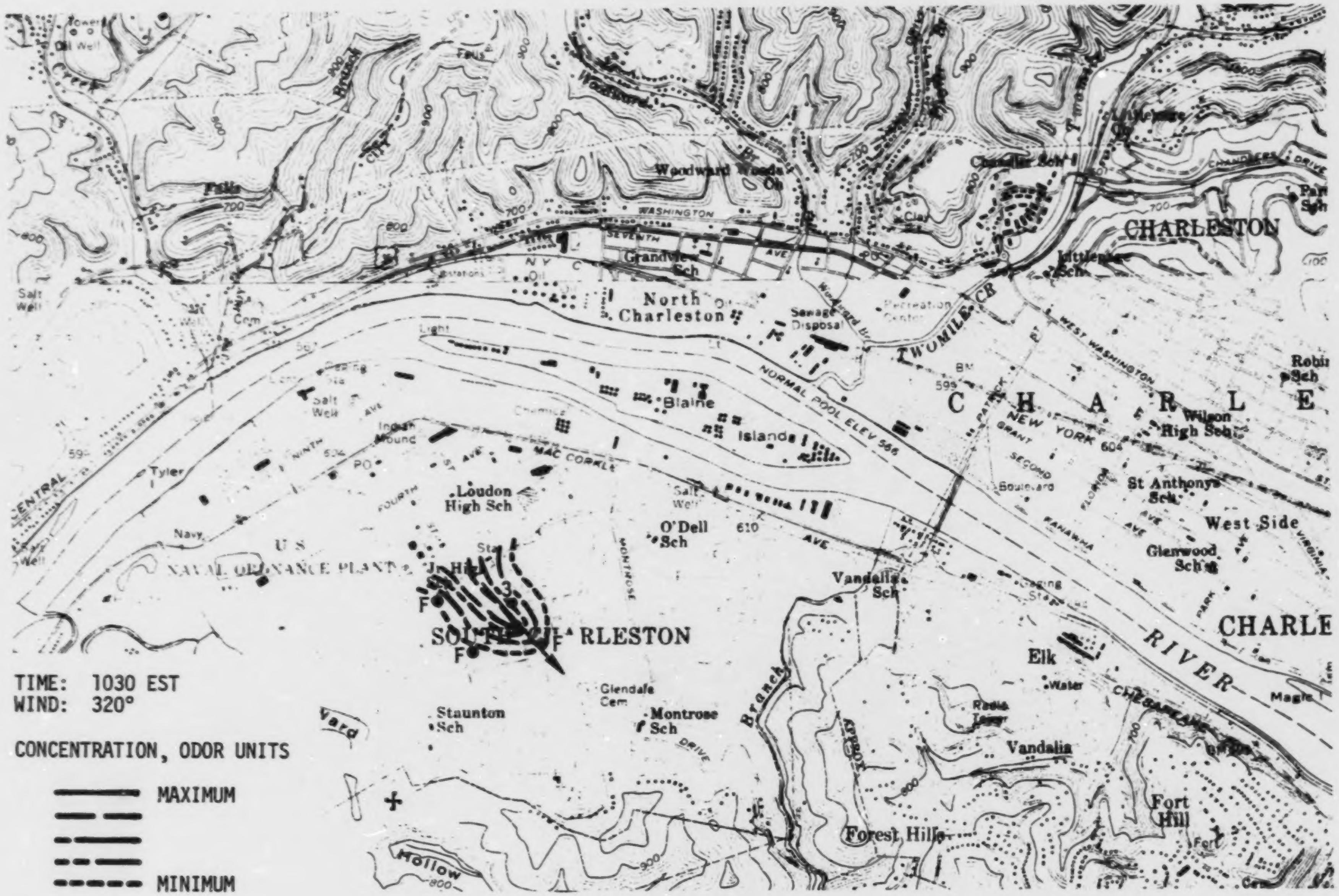

TIME: 1030 EST
WIND: 320°
CONCENTRATION, ODOR UNITS
MAXIMUM
MINIMUM
CHARLESTON
C H A R L E
CHARLE
RIVER
North Charleston
Grandview Sch
Woodward Woods
Chandler Sch
Sewage Disposal
Recreation Center
TWOMILE CR
WEST WASHINGTON
WASHINGTON
SEVENTH
NEW YORK
Wilson High Sch
St Anthonys Sch
West Side
Glenwood Sch
Blaine
Island
NORMAL POOL ELEV 566
MAC CORKLE
Loudon High Sch
O'Dell Sch
Salt Well
Indian Mound
Tyler
CENTRAL
Navy
U S NAVAL ORDNANCE PLANT
SOUTH CHARLESTON
Vandalia Sch
Vandalia
Elk
Water
Glendale Cem
Montrose Sch
Staunton Sch
MONTROSE
DRIVE
Branch
Forest Hills
Fort Hill
Hollow
CHESAPEAKE
Magic
Falls
Cem
F
3

Figure 4-63. Hydrogen sulfide odor found in the South Charleston area, July 20, 1966.

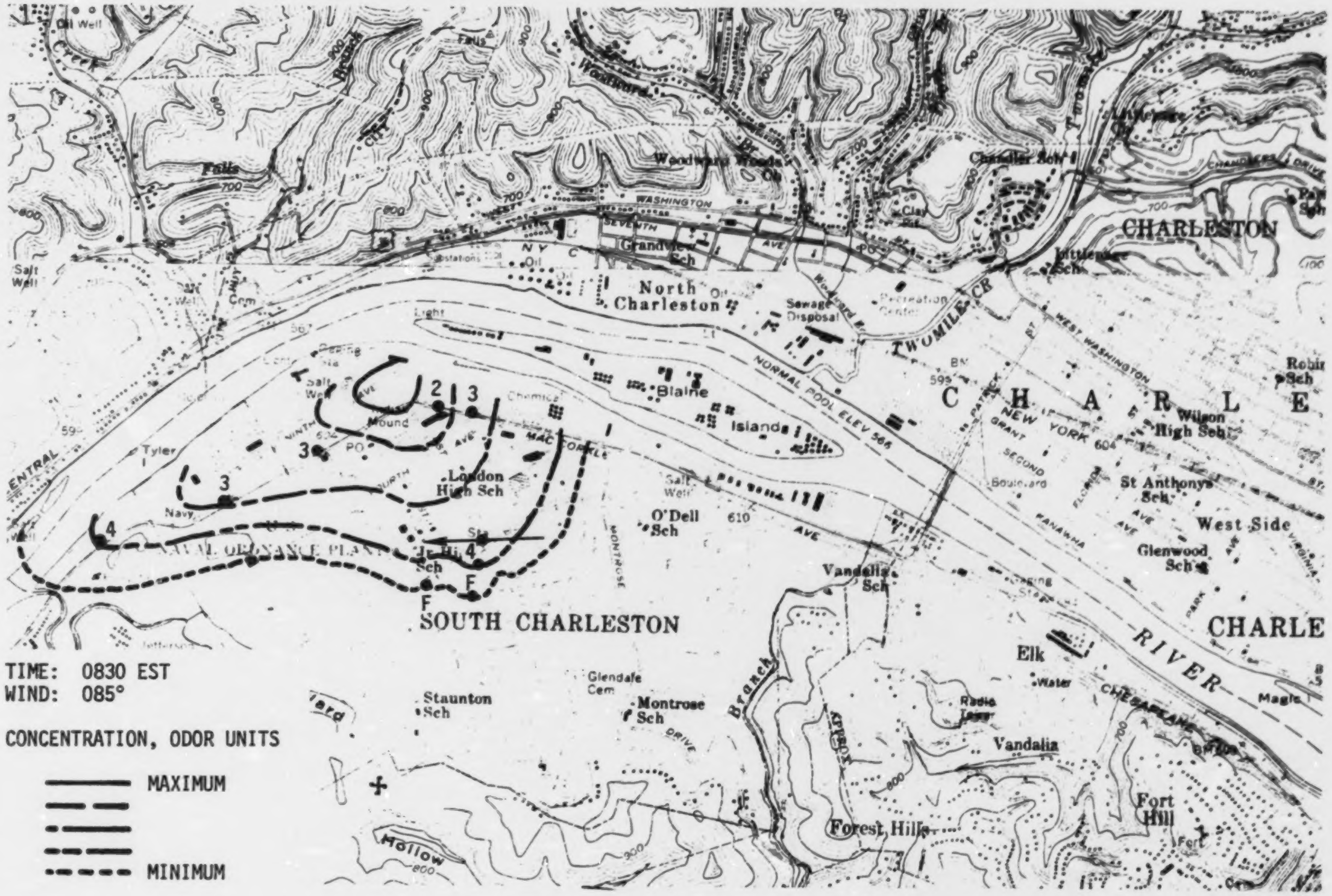

TIME: 0830 EST
WIND: 085°
CONCENTRATION, ODOR UNITS
MAXIMUM
MINIMUM
CHARLESTON
North Charleston
SOUTH CHARLESTON
CHARLE
C H A R L E
RIVER
NORMAL POOL ELEV 566
Blaine
Island
TWOMILE CR
Sewage Disposal
Grandview Sch
London High Sch
O'Dell Sch
Vandalia Sch
Staunton Sch
Montrose Sch
Glendale Cem
Forest Hills
Fort Hill
Vandalia
Elk
Wilson High Sch
St Anthonys Sch
West Side
Glenwood Sch
Woodward
Falls
NAVAL ORDNANCE PLANT
Mound
2
1
3
3
3
4
4
F
F

Figure 4-64. Hydrogen sulfide odor found in the South Charleston area, July 21, 1966.

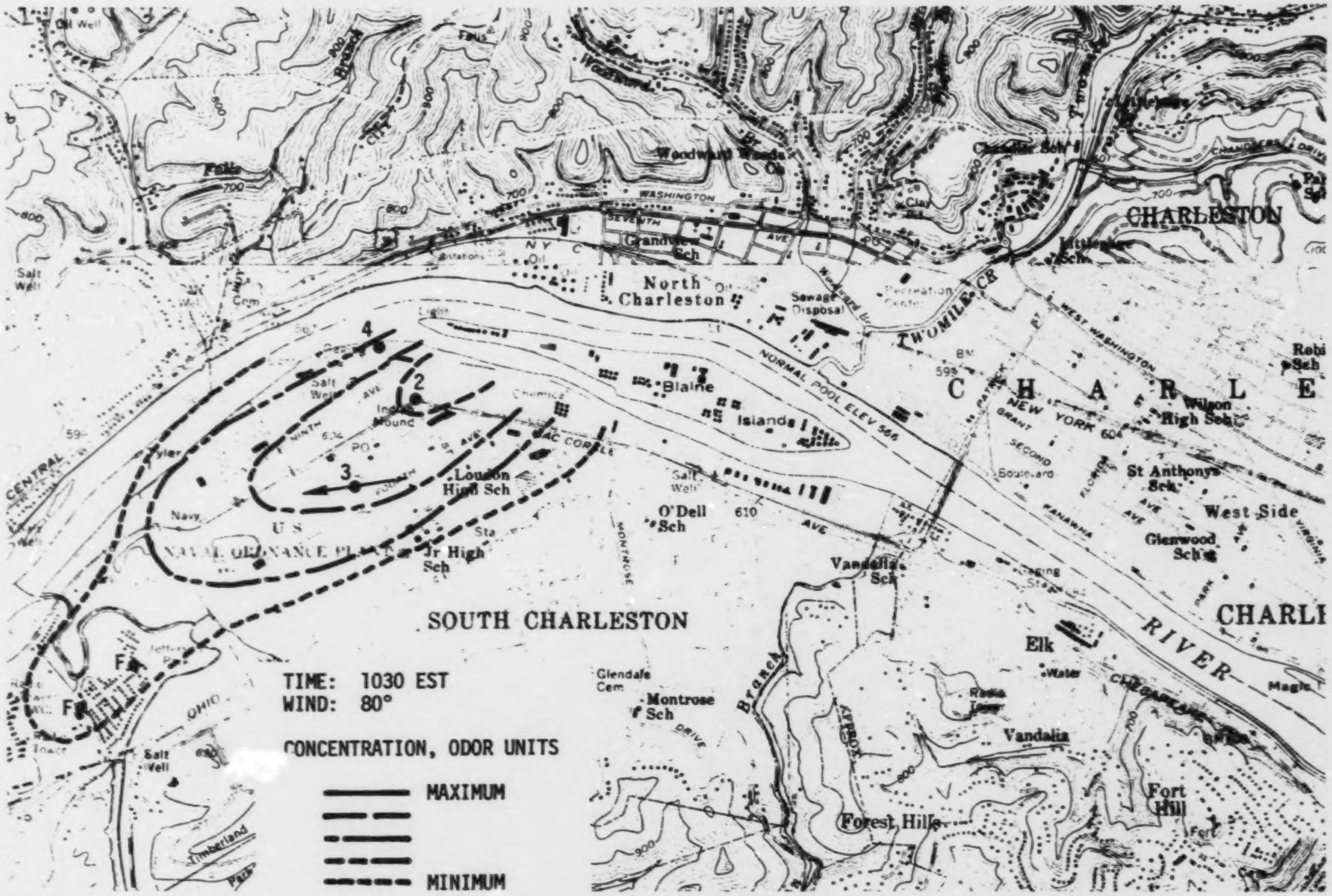

TIME: 1030 EST
WIND: 80°
CONCENTRATION, ODOR UNITS
MAXIMUM
MINIMUM
1
2
3
4
SOUTH CHARLESTON
CHARLESTON
North Charleston
Blaine
Islands
NORMAL POOL ELEV 566
RIVER
U S NAVAL ORDNANCE PLANT
Indian Mound
Loudon High Sch
Jr High Sch
O'Dell Sch
Montrose Sch
Vandalia Sch
Vandalia
Forest Hills
Fort Hill
Elk
West Side
Glenwood Sch
St Anthonys Sch
Wilson High Sch
Grandview Sch
Woodward
Sewage Disposal
TWOMILE CR
Glendale Cem
Salt Well
Navy
OHIO
Timberland
Branch

Figure 4-65. Hydrogen sulfide odor found in the South Charleston area, August 3, 1966.

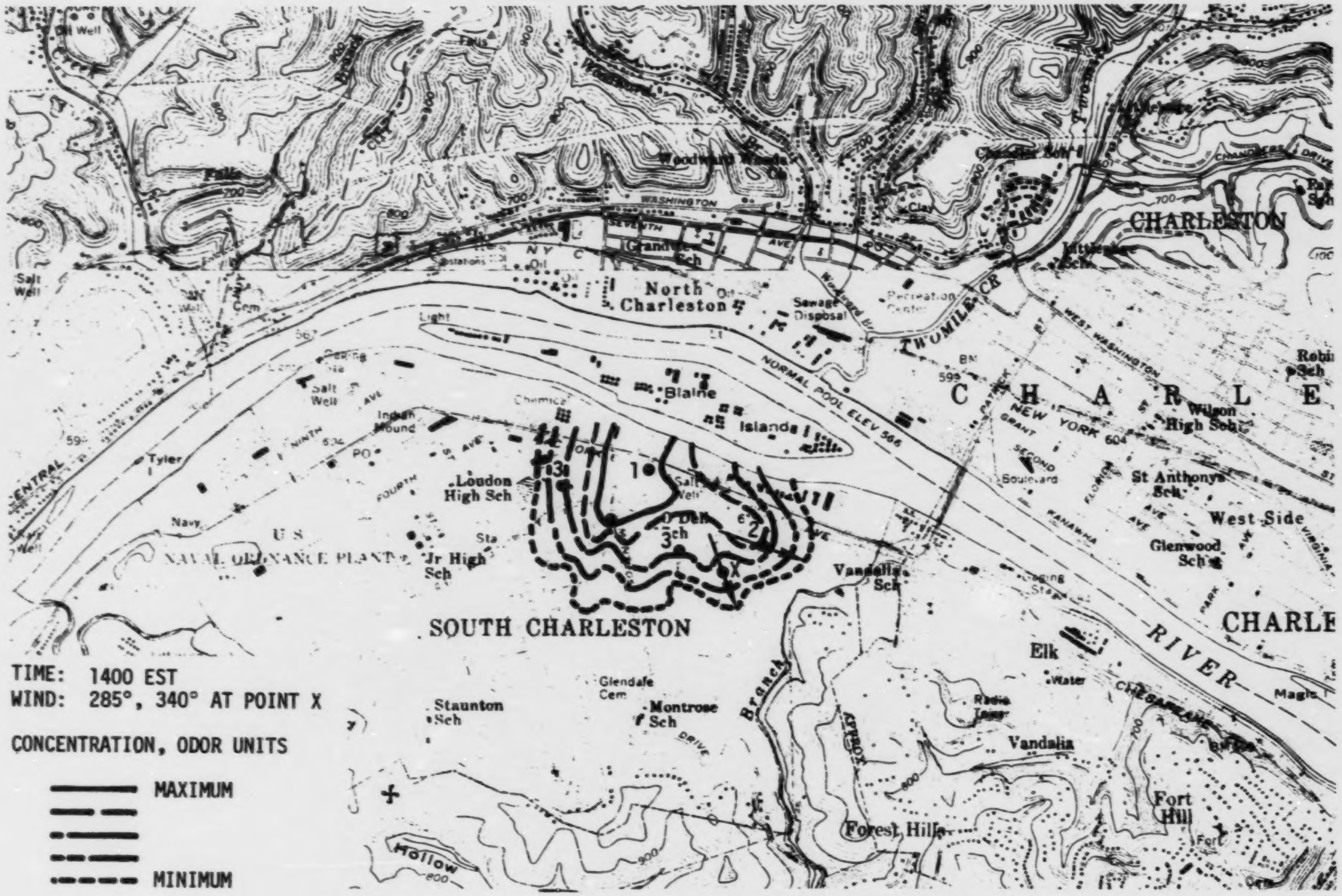
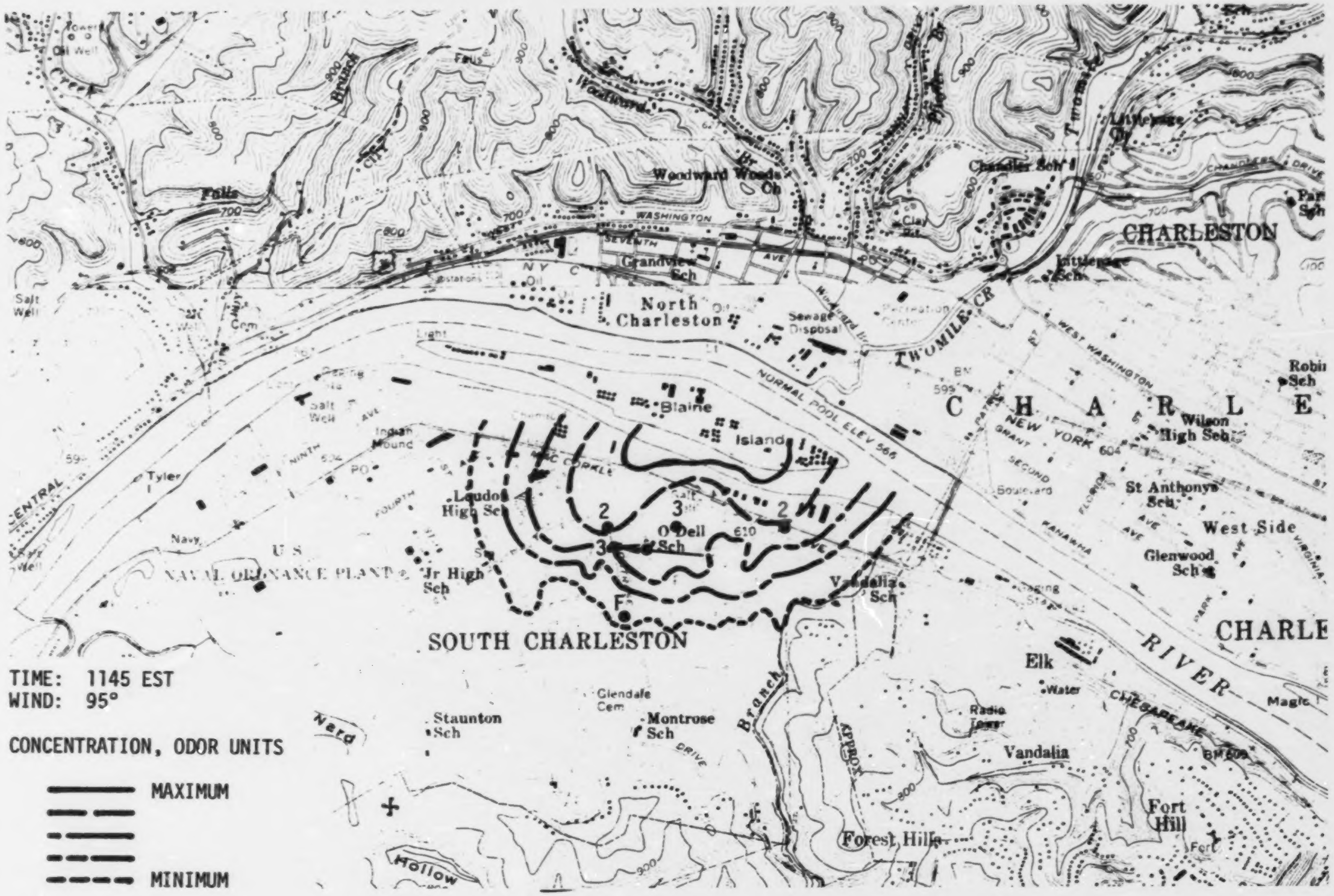

TIME: 1400 EST
WIND: 285°, 340° AT POINT X
CONCENTRATION, ODOR UNITS
MAXIMUM
MINIMUM
SOUTH CHARLESTON
North Charleston
CHARLESTON
C H A R L E
CHARLE
RIVER
NORMAL POOL ELEV 566
Blaine
Islands
U S NAVAL ORDNANCE PLANT
Loudon High Sch
Jr High Sch
O'Dell Sch
Vandalia Sch
Staunton Sch
Glendale Cem
Montrose Sch
Forest Hills
Fort Hill
Vandalia
Elk
West Side
Glenwood Sch
St Anthonys Sch
Wilson High Sch
Grandview Sch
Sewage Disposal
Recreation Center
Salt Well
Indian Mound
Tyler
Hollow
Branch
1
2
3
X

Figure 4-66. Odor described as rotten found in the South Charleston area, May 25, 1966.


TIME: 1145 EST
WIND: 95°
CONCENTRATION, ODOR UNITS
MAXIMUM
MINIMUM
CHARLESTON
North Charleston
SOUTH CHARLESTON
Blaine
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Woodward Woods Ch
Grandview Sch
Chandler Sch
Sewage Disposal
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NORMAL POOL ELEV 566
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St Anthonys Sch
West Side
Glenwood Sch
Loudon High Sch
O'Dell Sch
Vandalia Sch
Jr High Sch
U.S. NAVAL ORDNANCE PLANT
Staunton Sch
Montrose Sch
Glendale Cem
Elk
Vandalia
Fort Hill
Forest Hills
Branch
Hollow
Falls
Salt Well
Tyler
Navy
Indian Mound
2
3
3
2
3
F

Figure 4-67. Odor described as rotten found in the South Charleston area, August 3, 1966.

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SECTION V.
AIR RESOURCE MANAGEMENT PLAN

INTRODUCTION

An air resource management program - or an air use plan - has the objective of defining the specific concentrations of air pollutants which, if not exceeded, will maintain the quality of ambient air in a community at a level presenting no threat to the health and welfare of that community's citizens. These specific concentrations, referred to as air quality goals, have been selected by the sponsors of this study. The basis for their selection are reported in detail in Section IV.

Implementation of an air use plan is a means of relating the potential pollutant emissions of a community to acceptable air quality goals. Through an air use plan, consideration is given to the locations of pollutant sources in the area and the dilution capacity of the air. The air use plan thus becomes the basic framework for achieving desired air quality by limiting emissions from existing sources and by preplanning control of emissions from new sources. An air use plan, therefore, is a basic tool in community planning activities and in enacting regulations for the control and reduction of air pollution.

Emission sources, meteorology, and topography differ in each area where an air pollution survey is conducted. A common air use plan is impractical under these circumstances. Similarly, control regulations, when enacted, should be designed specifically to reduce the pollutants emitted by sources in the area of concern.

An air use plan is designed in two parts. The first part involves calculating the percentage reduction in pollutant emissions required to assure acceptable air quality, expressed as allowable emission rates. The second part involves the development of an implementation plan to achieve these reductions, expressed as reductions in emissions from the area's sources.

Design of an air use plan is complicated by the multiplicity and diversity of pollutant sources present in today's urban areas; the lack of complete data on emission rates and release heights; and the unreliability of current knowledge on the diffusion characteristics of the atmosphere, especially in and above the valley. In the study area, for example, an effort was made to determine the dilution capacity of the atmosphere by employing several simplifying assumptions, some of which have not been fully tested. Until more detailed emission and meteorological data become available, and better use of computerized diffusion models capable of considering all the important variables are perfected, however, the techniques used in developing an air use plan for the Kanawha Valley must provide an adequate framework for decision-making by including adequate safety factors.

The pollutants considered in the report include particulates, sulfur dioxide, hydrocarbons, carbon monoxide, oxides of nitrogen, and odors. Emission reduction plans have, however, been developed for particulates only, and sulfur dioxide. Carbon monoxide is emitted primarily by motor vehicles and is expected to be controlled on a nationwide scale at levels which should result in an adequate reduction in the Kanawha Valley. Photochemical air pollution, or "smog," is not a problem in the Kanawha Valley; therefore, emission of gaseous hydrocarbons and other organics will at present need only be considered from the standpoint of toxicity and odors. Oxides of nitrogen are becoming an increasing problem nationally; however, a more complete treatment of this pollutant during the study period was hampered by limited air quality data and lack of established air quality criteria. Because odors are generally associated with individual sources, a comprehensive reduction plan is not workable, and therefore, the discussion of odors is in more general terms.

The Kanawha Valley emission reduction plan is based upon the entire area, rather than by land use categories, since there is no clear distinction between industrial, commercial, and residential zones as there is in some other urban areas. A pollution source at one end of the valley may have its greatest effect some considerable distance away due primarily to the channeling effect of the valley topography as well as the emission release height and windspeed. Consequently, the emission reduction plan is based upon those areas with the maximum recorded concentrations.

Air use plans are not limited in usefulness to the setting of emission control regulations; they are also applicable to other aspects of urban planning. Encouragement should be given to planning agencies to utilize the information presented here, and to recognize that some of the best and least expensive ways of combatting air pollution may come within these responsibilities. For instance, future emission sources should be located in areas which are not now over-polluted.

Similarly, surveillance of air quality should be maintained as the emission reduction plan is implemented, so that a continuous refinement can be affected.

The air use plan must consider future growth. Control measures should limit current and future projections of emissions to a degree which will allow for expansion in the economy. Such expansion will include an increasing population density, greater numbers of motor vehicles, and increasing industrial output and power generation. To predict the economic expansion in the Kanawha Valley is difficult, even more difficult than the usual economic forecast, since the overall growth and the direction of growth of both the State of West Virginia and the Kanawha Valley is highly uncertain. A review of economic and planning reports for both the State of West Virginia and the Study area provide a number of forecasts, ranging from those reporting an increase in population and substantial growth in industry to those predicting a stabilization of both population and industry, with possible changes in the output of some industries.

Growth in both population and industry is forecast, yet allowing some expansion in emission sources and protecting the valley's air quality. The following estimates are the basis for the projection modes in the study. It is anticipated that population in the study area will increase to 255,000 persons by 1980. An increase in industrial output is expected by 1980, even though employment will not rise significantly because of increases in productivity levels. Increases in gasoline consumption and refuse generation are closely linked to the needs of inhabitants, and increase in direct ratio to growth in population. Vehicle gasoline consumption is expected to increase substantially. Refuse material generation is expected also to increase with rising population and its attendant per capita production of refuse.

PARTICULATES

Particulate matter is produced and discharged to the air of the community from many activities. Particulate matter, whether settleable or suspended, is the most common group of pollutants in urban areas. In the Kanawha Valley, the principal sources of this pollutant are the burning of high ash-containing fuels, certain industrial processes, and refuse disposal by burning. In terms of the quantity of particulate matter emitted to the air, a few large pollutant sources in the Kanawha Valley contribute about 95 percent of the total. A few smaller sources, including incineration of refuse and some industrial processes, are distributed throughout the area and their emissions cause some localized problems. In the design of the air use plan, both types of sources were considered.

Air Quality Goals

Particulate air quality goals are based upon the three common measures of particulates - suspended particles, dustfall, and soiling index. Suspended particulate was measured by high-volume air samplers which give a quantitative weight determination of those particles which remain suspended within the study area. Dustfall was measured by the "dustfall bucket" which likewise gives a weight determination of those particles which "settle-out" within the study area. Soiling index was measured by the tape sampler which indicates the soiling effect and reduction in visibility caused by suspended particles. These three measures of particulate pollution, while measuring different aspects of the problem, are interrelated. Because there is considerable overlap in the particulate characteristics from various sources, there is the likelihood that a reduction in one will influence the others. Actually the smaller the particle, the more difficult its emission is to control. Thus, if the reduction plan is able to meet the air quality goals for suspended particulate and soiling index, normally the dustfall goal will also be attained. Trial calculations indicated that the reductions in particulate emissions necessary to meet the suspended particulate goals will result in the achievement of the goals set for the other measures.

The desired goals for particulate matter are summarized in Table 5-1. These goals are applicable to all areas where people live or work. These goals were recommended and approved by the Joint Study Technical Committee at a meeting held August 7, 1967. These goals may need revision in accordance with air quality criteria for particulate matter issued by the National Air Pollution Control Administration as required by the 1967 amendments to the Clean Air Act.

The Kanawha Valley goals for suspended particulate are based upon an annual geometric mean desirable for preventing long-term effects and a 99 percentile value to prevent occurrence of detrimental short-term effects. However, the reduction plan is based only upon the average annual geometric mean value, since trial calculations indicate that if this goal is achieved, then the 99 percentile goal of 250 micrograms per cubic meter will also be attained.

Existing Air Quality

Summaries of particulate measurements made in Kanawha Valley have been presented in Section IV. As mentioned earlier, the high-volume sampler measurements of suspended particulates were the controlling factor in developing the particulate emission reduction plan.

Table 5-1. PARTICULATE AIR QUALITY GOALS

Type of particulate	Goal, August 1967[a]		Criteria conclusions[b]	
Suspended particulate, micrograms per cubic meter	100	Annual geometric mean	80 - 100	Annual geometric mean, adverse health effects
			60 - 180	Annual geometric mean, adverse effects on materials
	250	Maximum not to be exceeded more than 1 percent of days per year	150	At any time, reduction of visibility to about 5 miles
Settleable particulate, (dustfall), tons per square mile per month	20	Annual geometric mean, residential and commercial		
	35	Annual geometric mean, industrial		
Suspended particulate (soiling index), Cohs per 1,000 linear feet	0.5	Annual geometric mean		

[a] Based on information available to the Committee in August 1967.

[b] Air Quality Criteria for Particulate Matter, National Air Pollution Control Administration Publication No. AP-49, Washington, D. C., January 1969.

The 14 high-volume sampling stations recorded yearly geometric mean concentrations of suspended particulates ranging from 110 to 332 micrograms per cubic meter. The decision of the Joint Study Committee was to average measurements at the two highest stations in the network. If the air quality goal is achieved at these stations, the goal will also be attained throughout the valley area. While the Montgomery station recorded the highest geometric mean, this data was not used because of the proximity of the sampling site to a significant local point source; the study staff did not consider the data representative of the area. The two stations chosen were Smithers and South Charleston East, which have an average geometric mean concentration of 272 micrograms per cubic meter. It should be noted that the geometric mean annual concentration of suspended particulate for these two stations exceeded the goal of 100 micrograms per cubic meter for the entire study area.

The 27-station dustfall sampling network recorded settled particulate values ranging from 10 to 175 tons per square mile per month, on an annual geometric mean basis. The two highest stations recorded values of 100 and 175 tons per square mile per month at Boomer and Montgomery Heights, respectively. The average of these two high dustfall areas is 138 tons per square mile per month. Relating to the air quality goal, the geometric mean annual concentration of settleable particulate exceeds the goal of 20 tons per square mile per month for residential and commercial zones in most parts of the Kanawha Valley and is particularly high in certain areas.

The 14-station A.I.S.I. sampling stations recorded annual average geometric mean values of soiling index ranging from 0.4 to 1.0 Cohs per 1,000 linear feet. The average of the two highest stations in the network is 0.9 Cohs per 1,000 linear feet. Again, the geometric mean annual values of soiling index exceeds the air quality goal of 0.5 Cohs per 1,000 linear feet in most of the Kanawha Valley.

Existing Emissions

Approximately 364 tons of particulate are presently emitted daily to the atmosphere in Kanawha Valley from all sources. The primary sources of particulate are from coal combustion in utility and industrial furnaces, from industrial process emissions, particularly acid mist and metallurgical fumes and dust, and from open burning of refuse. Table 5-2 presents a summary of daily particulate emissions by source category. See Section III - Emission Inventory for additional information. Also presented in Table 5-2 is a breakdown into suspended and settleable particulate, which is an essential factor in the relationship between air quality and measured particulate emissions.

Table 5-2. PARTICULATE EMISSIONS IN KANAWHA VALLEY, 1965
(tons/day)

Source	Total particulate emission	Suspended particulate <44 micron	Settleable particulate >44 micron	Respirable particulate <5 micron
Combustion, heat and power generation	299.7	256.6	43.2	18.3
Transportation, mobile sources	3.0	3.0	-	3.0
Processes				
Chemical	26.8	26.5	0.3	25.0
Metallurgical	21.7	21.5	0.2	16.4
Glass and ceramics	1.2	1.2	-	1.0
Aspnalt batching	0.7	0.6	0.1	0.4
Concrete batching	0.2	0.2	-	0.2
Lumber	0.2	0.1	0.1	-
Fabrication	0.2	0.1	0.1	-
Total	51.0	50.2	0.8	
Waste disposal				
Burning dump	4.2	2.1	2.1	0.5
Backyard burning	5.0	2.5	2.5	0.5
Single-chamber incinerator	0.3	0.2	0.1	0.1
Multiple-chamber incinerator	0.3	0.2	0.1	0.1
Total	9.9	5.0	4.8	
Total	363.6	314.8	48.8	65.5

Using this approach, approximately 315 tons per day of the particulates emitted are less than 44 microns and thus considered suspended and 49 tons per day are greater than 44 microns and thus considered settleable particulate. These calculations are based on control measures and 1965 particle-size emission estimates, when the emission inventory was conducted. While these are only estimates, the calculations should provide a reasonable basis for developing a reduction plan to meet the air quality goals for particulates. Following is an explanation of the methodology used.

Relationship Between Air Quality and Emissions

The ambient air concentrations of suspended particulates, dustfall, and soiling index are dependent upon the total quantity of particulates emitted to the air basin, the particle-size distribution of the emissions, the types and elevations of the sources, the meteorology and diffusion capacity of the air basin, the geographical distribution of the emissions, and, also, the daily variations which occur in emissions. In order to attain air quality goals, even in the most unpolluted area, consideration must be given to all of these factors. The ideal situation would be to develop a mathematical model which would simulate all these factors and predict the reduction in emissions needed to meet ambient air quality goals.

Source Reduction Technique - An indirect approach is used to determine the needed reduction in emissions to achieve the air quality goals, to avoid the complications of considering directly the influence of source elevation, diurnal variation in emissions, and diffusion capacity of the air basin. The technique was developed by Larson and has been used in various community studies.[1,2,3,4] Basically, the approach involves a comparison of measured air quality with established air quality goals. The same percent of reduction in existing levels of suspended particulate needed to achieve the air quality goals is applied to the needed reduction in source emissions of suspended particulate. Background levels which are irreducible are considered when calculating the percent reduction in emissions required to meet the air quality goal.

A cumulative frequency of occurrence of suspended particulate concentrations for Smithers and South Charleston stations is plotted in Figure 5-1. Also plotted are the air quality goals for suspended particulates. The geometric mean and 99th percentile goals are connected to indicate a desirable frequency distribution. Background suspended particulate, as measured at Holly River State Park (National Air Sampling Network, 1957-1961), is also included on this plot.

The overall-average air quality control required to meet a given standard is calculated as follows:

$$\text{Percent Source Reduction} = \frac{100\,(C-S)}{C-B}$$

Where C is the measured air quality concentration
S is the air quality standard
B is the background concentration

This equation relates source emissions and air quality concentrations, and corrects for background levels which are irreducible so that a given reduction in particulate emissions which remain suspended will reduce suspended particulate concentrations by the same amount. An important assumption in using this equation is that measurements of suspended particulate concentrations were made over a sufficient length of time to minimize variations occurring in meteorological conditions

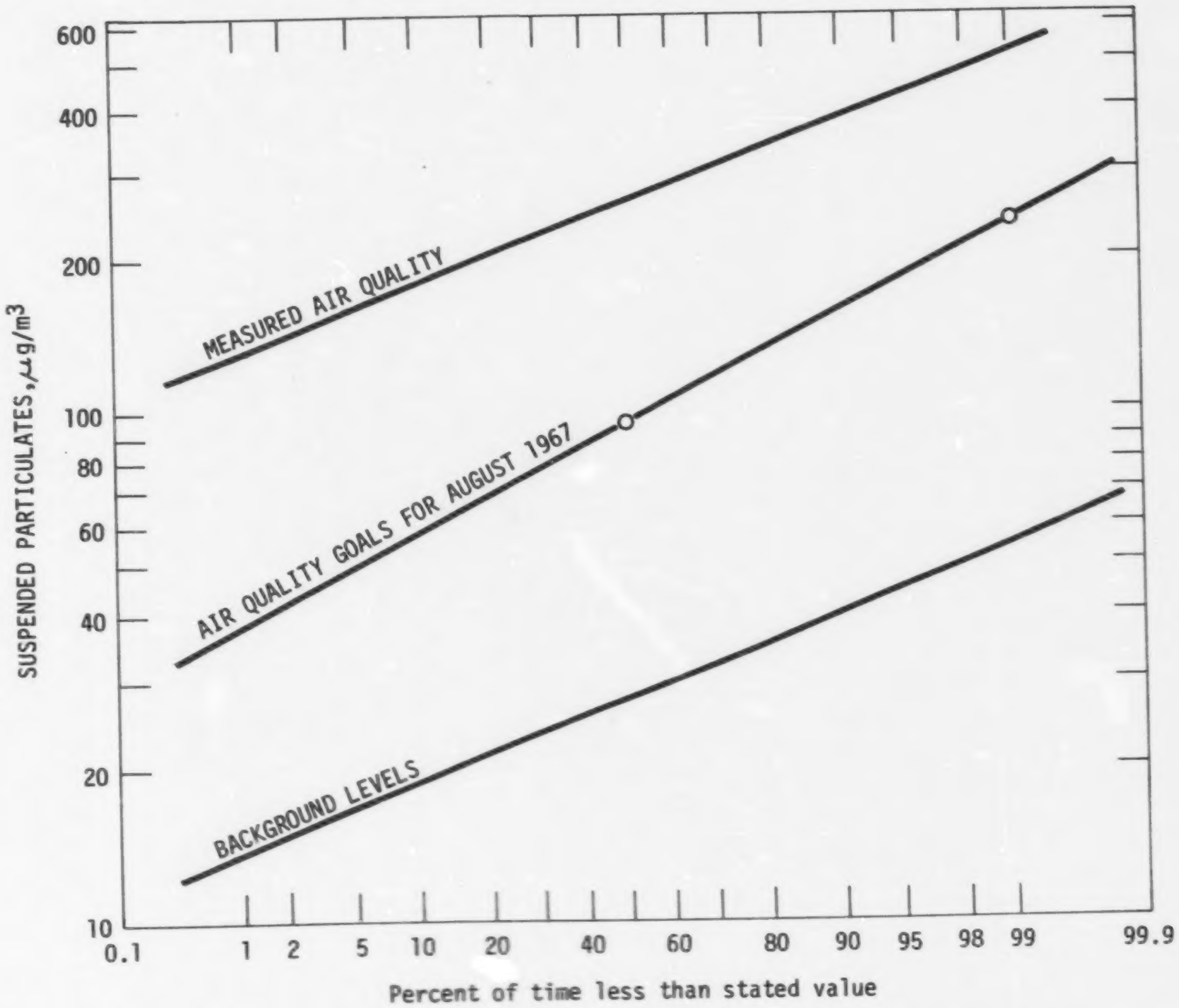

Figure 5-1. Suspended particulates cumulative frequency distribution for Kanawha Valley, West Virginia.

and particulate emission rates. The 2 years of data available for this study are believed to be sufficient.

Calculations using Figure 5-1 show that a greater percent reduction is needed to meet the 50th percentile goal of 100 micrograms per cubic meter than the 99th percentile goal of 250 micrograms per cubic meter at the source. By substituting in the equation, the percent source reduction needed can be calculated:

$$\text{Percent Reduction} = \frac{100\ (272 - 100)}{272 - 28} = 71$$

This means that a 71 percent overall reduction is required only in those particulate emissions which remain suspended. In the same manner, similar calculations indicate that a 93 percent reduction in settleable particulate, or dustfall, is needed to meet a goal of 20 tons per square mile per month.

Particulate Samplers and Particle Size Measurement - Particulate emissions are measured with both high-volume samplers and dustfall bucket samplers. Some correlation must be established concerning the amount of particulates emitted and that portion actually being measured by the various instruments.

The high-volume sampler is capable of collecting particulates from the air of about 100 microns and less in diameter (settling velocity = 64 fpm). Preliminary results obtained in five large cities indicate that about 50 percent of the particles collected, by weight, are less than 3.5 microns.[5] Another study indicated that nearly two-thirds of the particles by weight are less than 10 microns.[6] This study also found that about 50 percent of the particles by weight are in the size range of about 3.5 microns which can penetrate the lower respiratory tract.[6] Assuming a log-normal distribution of the particles, it can be predicted that about 95 percent of the particles collected by the high-volume sampler are less than 44 microns in size. Particles of this size are a sub-seive size which will pass a 325-mesh tyler screen. Certain studies, and some air pollution regulations, have used this size particle as the break between suspended and settleable particulate.

Dustfall buckets collect particles as low as 30 microns in size and higher.[7] They can be a true measure of settleable particulate emissions in a community, if the sampling sites are properly located.

In the range of 30 to 100 microns, both the high-volume sampler and the dustfall bucket are capable tools of measurement. No one single particle size represents a sharp boundary between suspended and settleable particulate matter, although particles 10 microns and less are usually considered to be suspended indefinitely. Whether the particle is measured as dustfall or suspended particulate depends primarily on meteorological factors. The distances to which spherical particles of various sizes and density will be transported before settling is determined by "effective" stack height and wind speed under ideal conditions of steady nonturbulent flow, as predicted by Stokes law. Since these conditions are constantly changing, the airborne characteristics of suspended and settleable particulate matter are likewise changing. This fact was illustrated at some of the sampling stations when a decrease in suspended particulate, as recorded by the high-volume sampler, resulted in a simultaneous increase in dustfall.

In order to more realistically develop a particulate reduction plan, an assumption was made regarding settleable and suspended particulate. The choice of a 44 micron split seems to be reasonable, particularly since it is probable that 95 percent by weight of the material collected on the high-volume filter will be less than this size.

Allowable Particulate Emission - Some 315 tons per day of particulate emission is considered suspended particulate and 49 tons per day settleable particulate, based on a 44 micron diameter "split." To meet the goals for the Kanawha Valley Study Area, 71 percent reduction in suspended particulate and 93 percent reduction in settleable particulate emissions has been established as the requirement. Based on these estimates an allowable emission rate of particulate emissions can be calculated. Table 5-3 presents the results. An allowable emission rate of 91 tons per day of suspended particulate and 3 tons per day of settleable particulate was estimated.

Table 5-3. PRESENT ALLOWABLE PARTICULATE EMISSION

Type of particulate	Air quality goal, annual geo. mean	Present air quality, annual geo. mean	Reduction needed, percent	Present particulate, ton/day	Allowable particulate emissions, ton/day
Suspended particulate, micrograms per cubic meter	100	272	71	315	91
Settleable particulate, ton/sq mi/month	20	138	93	49	3

The revised estimations of allowable particulate emissions are based only on current 1965 emission rates, plus a 25 percent allowance for the increased emission rates connected with projected industrial growth and power consumption by 1980. Under these circumstances, expected growth will not exceed the air quality goals. If growth exceeds the estimates, the emission reduction plan for particulate matter will need revision.

Particulate Reduction Plan

The existing and allowable emissions have been established. The purpose of the emission reduction plan is to determine the control regulations required to reduce existing emissions to levels that will meet air quality goals and will allow for future growth within these limits. Consideration must also be given to the technical and economic feasibility of the plan. Control regulations which are enforceable and use the most sophisticated technology must be the only ones considered in order to make the plan effective.

The discussion of the emission reduction plan is divided into three categories, namely combustion, industrial process, and refuse disposal. Present day technology is not sufficiently advanced to effectively control particulate emissions from transportation sources, including automobiles, diesel vehicles, and aircraft, and therefore, transportation particulate has not been included in the emission reduction plan. Programs to limit emissions from fuel combustion, industrial processes, and refuse disposal are designed and presented. The enacted and proposed control regualtions are expected to reduce particulate emissions to within allowable limits and also allow for future growth of the area.

Combustion - Heat and power generation contributed a total of about 300 tons per year of particulate matter in the Kanawha Valley in 1965. Due to the immediate need for relief from the effects of particulate air pollution and since sufficient data was available on suspended particulate measurements and emissions, a regulation for the control of particulate emissions from boiler plants was developed and drafted by the study staff and the Joint Study Technical Committee. The draft was sent to the West Virginia Air Pollution Control Commission for consideration. The Commission, on December 11, 1965, held the legally required public hearing. After consideration of the comments of numerous interested parties, a slightly modified regulation was promulgated by the Commission and became effective April 4, 1966.

This regulation was developed by the study staff using information available on each combustion source. Factors considered were method of firing, firing rates, fuel characteristics, installed control equipment, present estimated emissions, and the allowable emissions from the various sources. The study staff using this information developed an emission control program based on boiler size (Btu per hour) versus maximum allowable emissions (pounds per million Btu). Figure 5-2 presents a plot of the final adopted combustion equipment regulation. A more restrictive curve is used for newly designed equipment than for existing fuel-burning equipment. A sliding scale is used in both cases - a lesser degree of control is required on smaller sources, with the degree of control increasing proportionately with the size of the combustion unit. This approach is considered both practical and equitable since larger sources have a higher emission potential generally and the installation of more efficient control devices is more feasible.

The scheduled reduction plans were presented to the Commission as required by the regulation. It is expected that they will be completed by 1973 on all existing equipment. Essentially this regulation will reduce existing particulate emission by about 80 percent when fully implemented.

Industrial Process - Industrial processes emit a total of 51 tons of particulate matter per day to the atmosphere in the Kanawha Valley Study Area. Substantial reductions must be made in industrial process emissions, in addition to the regulation of emissions from fuel combustion sources. In terms of applicability, various control schemes were investigated. In these investigations, economic and technical capability were taken into consideration. The suggested emission limitation scale based on the process weight concept which is a direct method of limiting the weight discharge from a source based on the weight input to the process. This approach has been found to be a practical and adequate means of reaching desired reductions in process particulate emissions when combined with limitations on plume opacity. This approach is superior to concentration based standards which cannot be related directly to weight discharge in a non-combustion operation. Basing allowable weight discharge on process weight input also allows constructing a "sliding scale" standard which requires a greater degree of control as a specific process increases in size. Table 5-4 is such a standard. This approach is justified since potential emissions are greater from larger process units and the expense of high-efficiency control equipment is less burdensome for a larger installation.

Essentially the proposed standard requires a reduction in total particulate emissions of about 80 percent for small operations and 95 percent or more for larger operations.

In the case of sulfuric acid mist emissions, the following regulation shall apply in keeping with current control technology for sulfuric acid plants.

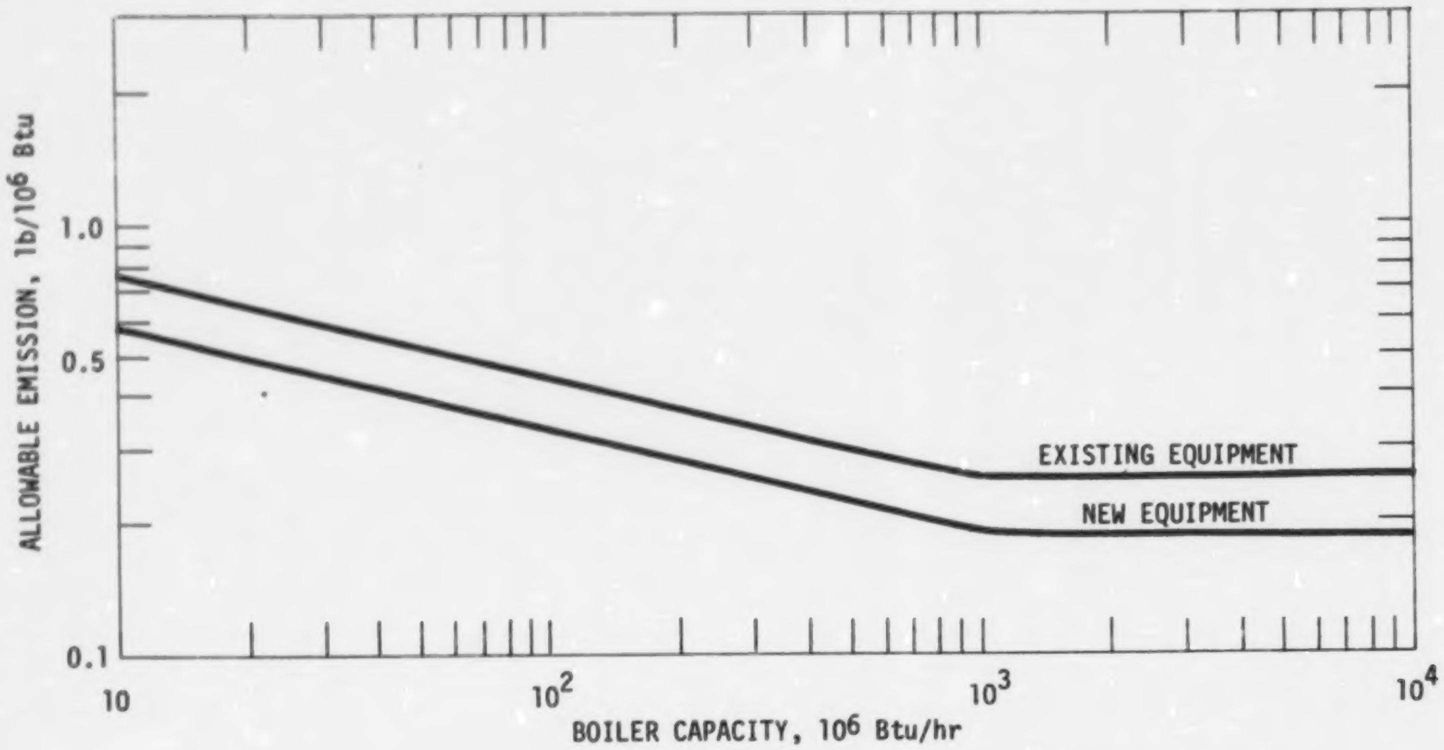

Figure 5-2. Kanawha Valley particulate matter emission standard for Fuel burning equipment.

Table 5-4. ALLOWABLE RATE OF EMISSION BASED ON PROCESS WEIGHT RATE[a]
(lb/hr)

Process weight rate	Rate of emission	Process weight rate	Rate of emission
100	0.551	16,000	16.5
200	0.877	18,000	17.9
400	1.40	20,000	19.2
600	1.83	30,000	25.2
800	2.22	40,000	30.5
1,000	2.58	50,000	35.4
1,500	3.38	60,000	40.0
2,000	4.10	70,000	41.3
2,500	4.76	80,000	42.5
3,000	5.38	90,000	43.6
3,500	5.96	100,000	44.6
4,000	6.52	120,000	46.3
5,000	7.58	140,000	47.8
6,000	8.56	160,000	49.0
7,000	9.49	200,000	51.2
8,000	10.4	1,000,000	69.0
9,000	11.2	2,000,000	77.6
10,000	12.0	6,000,000	92.7
12,000	13.6		

[a] Interpolation of the data in this table for process weight rates up to 60,000 lb/hr shall be accomplished by use of the equation $E = 4.10 P^{0.67}$ and interpolation and extrapolation of the data for process weight rates in excess of 60,000 lb/hr shall be accomplished by use of the equation:

$E = 55.0P^{0.11} - 40$, where E = rate of emission (lb/hr) and P = process weight rate (tons/hr).

Sulfuric Acid Mist and/or Sulfur Trioxide
(Expressed as sulfuric acid)

Existing Equipment 70 mg/m^3
New Equipment 35 mg/m^3

The proposed process weight regulation and the sulfuric acid mist regulation should reduce existing processing plant emissions from about 51 to 9 tons per day, which is an 82 percent overall reduction. This is comparable to the 80 percent overall reduction of existing emissions of fuel combustion particulate required by Regulation II. In addition, asphalt batch plants are required to reduce existing emissions by approximately 85 percent overall under Regulation III.

An important part of the proposed process regulations are the particulate opacity requirements. In essence these regulations require that the emission of particulate matter shall not be darker in shade or appearance nor of such opacity as to obscure an observer's view to a degree equal to or greater than No. 1 on the Ringelmann Smoke Chart. Exceptions are made for start-up operations in which emission of particulate less than No. 3 Ringelmann is allowed for a period not to exceed 4 minutes during start-up. This regulation as applied to process emissions is designed to limit the emission of these small-size particles which, when measured on a weight basis, may meet other legal requirements such as the process weight curve. It is desirable to control the emission of sub-micron particulate since they are largely responsible for visibility reduction and, because they are in the respirable range, can adversely effect human health. In addition, regulation of particulate opacity is one of the more effective tools available to a control agency in reducing particulate emissions. At least 75 air pollution control agencies in this country have adopted Ringelmann and equivalent opacity regulations. The use of this concept has been upheld by the courts.

Refuse Disposal - Approximately 10 tons of particulate material is emitted daily from the burning of refuse material in the Kanawha Valley. Included are estimated emissions from open burning and incinerators. In addition to contributing to the total particulate load, open burning and poorly designed and operated incinerators are a constant source of complaints by the community. Open burning alone emits some 9.2 tons of particulate matter per day to the atmosphere of the Kanawha Valley and is a primary source of smoke, hydrocarbons, and odors. The severity of smoke, odors, and particulate matter emitted from incinerators varies considerably and depends upon the design and operation of the incinerator. The emissions of particulate matter from incinerators of the multiple-chamber design are less than the single-chamber design by factors ranging from four to ten.

In order to reduce particulate and odor emissions in the Kanawha Valley and minimize the adverse effects associated with excessive smoke and odors, open burning of refuse should be prohibited, and the only incinerators permitted should be of the multiple-chamber or a design equally effective for air pollution control. Prohibition of open burning carries the responsibility for providing methods for refuse collection and alternate methods of disposal. A maximum period of 3 years appears reasonable to allow for the development of full collection and disposal capability. To insure that incinerators are properly operated, an additional requirement limiting the emissions of particulate matter to 0.3 grains per standard cubic foot for installations burning less than 200 pounds of refuse per hour and 0.2 grains per standard cubic foot for larger sizes should be included. A small properly designed and operated multiple-chamber incinerator can meet these limitations in many cases without additional air pollution control devices. Larger incinerators will require low- to medium-efficiency scrubbers.

The complete elimination of open burning should reduce particulate emissions by some 9 tons per day. Refuse material should be disposed of either in controlled municipal incinerators or preferably by sanitary landfill practices. If such incinerators are controlled so as to limit emissions to recommended levels, the overall reduction in refuse incineration emissions should be about 90 percent.

Impact of Proposed and Adopted Regulations on Emissions

The expected reduction in particulate emissions from each of the source categories as a result of the present and proposed regulations has been discussed previously. Table 5-5 presents a summary of the total expected particulate emissions by source based on the full implementation of the adopted and proposed regulations of the West Virginia Air Pollution Control Commission. Such an emission

Table 5-5. PARTICULATE EMISSIONS AFTER CONTROL

Source	Total particulate, tons/day
Combustion (heat and power generation)	60.0
Transportation (mobile sources)	3.0
Industrial processes	
Chemical	6.5
Metallurgical	1.0
Glass and ceramics	1.2
Asphalt batching	0.1
Concrete batching	0.1
Lumber	0.1
Fabrication	0.1
Total	9.1
Waste disposal	
Burning dump	0
Backyard burning	0
Incinerators	1.0
Total	1.0
Total expected particulate	73.1
Allowable particulate, tons/day	91
Percent for future growth	25

reduction plan should reduce settleable particulate to a negligible level. Comparison of the allowable and the planned or expected particulate emissions shows that the emission reduction plan provides for sufficient reduction for the Kanawha Valley as a whole. The difference between the allowable and expected emissions in Table 5-5 is considered as the quantity of particulate matter than can be added to the air without exceeding the air quality goals established by the Commission for particulates. In effect, this allows for future expansion of existing sources and the addition of new pollution sources in the area. Time is also allowed for the emission reduction plan to be implemented. An increase of approximately 25 percent in total particulate emission is made for this purpose, as indicated earlier.

As required by the Clean Air Act, as amended, this emission reduction plan should be reevaluated in accordance with criteria for particulate matter issued by the U.S. Department of Health, Education, and Welfare.

SULFUR DIOXIDE

Sulfur dioxide is emitted during the burning of sulfur bearing fuels, the burning of waste sulfide compounds, and in the manufacture of sulfuric acid. The basic approach to reducing sulfur emissions from the burning of fuels is to use a fuel with a lower content of sulfur. The emissions of sulfur dioxide from sulfuric acid manufacture can be reduced either by improving the conversion efficiency of sulfur dioxide to sulfur trioxide and absorbing the sulfur trioxide to form additional sulfuric acid or by scrubbing the sulfur dioxide from the exit gases. Waste sulfide gases can be controlled by alkaline scrubbing or by reacting the sulfide gases in bauxite catalyst converters to form sulfur.

Air Quality Goals

The recommended air quality goals for sulfur oxides (measured as sulfur dioxide) in the study area are based on effects. These goals specify that the average 24 hour sulfur dioxide concentration should not exceed 0.1 ppm, more than 1 percent of the time, and that the average hourly concentration should not exceed 0.25 ppm more than 1 percent of the time. These goals should apply to any place where people live, or where undesirable effects could occur if the specified concentrations are exceeded. In the Kanawha Valley, residential, commercial, and industrial areas are essentially integrated; thus, the limits recommended should apply to the complete area. These air quality goals for sulfur oxides were recommended and approved by the Joint Study Technical Committee.

The sulfur dioxide reduction plan is based only upon the 24-hour goal of 0.1 ppm not to be exceeded more than 1 percent of the time. Trial calculations indicate that if this goal is achieved, then the goal of 0.25 ppm over a 1 hour sampling time not to be exceeded more than 1 percent of the time will also be attained by the proposed alternate reduction plans.

Existing Air Quality

Sulfur dioxide was measured at six sites by instruments on the U.S. Public Health Service mobile laboratory. The measurements were made for 1/2-hour, 1-hour, and 24-hour averaging times. The data are summarized in Section IV. Based on 24-hour averaging times, North Charleston, South Charleston, and Nitro each had three occurrences where the sulfur dioxide concentration exceeded 0.1 ppm, the proposed limit. There was a range of concentrations for all the stations of 0.01 ppm (the minimum detectable concentration) to a maximum of 0.16 ppm at the South Charleston station. Nitro (Junior High School) had the second highest occurrence with 0.15 ppm maximum and North Charleston the third highest occurrence with 0.14 ppm maximum. Based on a 1-hour averaging time, North Charleston had seven occurrences and South Charleston had two occurrences where a concentration of 0.25 ppm of sulfur dioxide was exceeded. South Charleston had the highest maximum concentration of sulfur dioxide, 0.46 ppm (winter, 1965). The second and third highest maximum concentrations of sulfur dioxide were found in Nitro, 0.41 ppm (spring, 1965) and North Charleston, 0.37 ppm (fall, 1965). The air quality goals for sulfur dioxide were exceeded in South Charleston, North Charleston, and Nitro (Junior High School) on the basis of data obtained during 1964 and 1965.

Because the sulfur dioxide concentrations (as measured by the Davis conductivity instrument-mobile laboratory) exceeded the sulfur dioxide air quality goal, sampling was initiated on a permanent basis in South Charleston, North Charleston, and Nitro in the fall of 1966 and is being continued. The sampling procedure being used is the 24-hour West-Gaeke with the Scaringelli modification.

The results of this continuing sampling validate the previous measurements of the mobile station for North and South Charleston. However, the results in the Nitro area indicate that the air quality goal was not exceeded for 480 24-hour measurements. This discrepancy between the mobile station and the permanent station may be explained by the change of sampling method and by the fact that the mobile station was at Nitro for a period of only 19 days. However, a review of sulfation results for the Nitro area indicates the occurrence of sulfur-related compounds at levels comparable to those found in North and South Charleston. The high levels could be the result of pollutants other than sulfur dioxide, viz. sulfur trioxide, sulfuric acid mist, mercaptans, and/or the physical location of the sampling site (a platform in an open field and not on the roof of a building). Further study of these pollutants in the Nitro area is necessary.

In view of these continuing sampling measurements of sulfur dioxide, emission reduction plans appear essential for only the North and South Charleston areas of the Kanawha Valley at this time. However, all practical steps should be taken to minimize the emission of sulfur oxides in all areas of the Kanawha Valley and especially the Nitro area to prevent adverse effects and to enhance the quality of the air.

Existing Emissions

Approximately 297 tons of sulfur dioxide are emitted daily from various industrial sources in the study area. A breakdown of these emissions by location and source is given in Table 5-6. Additional data on sulfur oxides emission are given in Section III; Emission Inventory.

Table 5-6. SULFUR DIOXIDE EMISSIONS
(tons/day)

Location	Coal burning	Chemical processes	Total
Nitro	15.3	12.7	28.0
Institute	42.2	0.1	42.3
South Charleston	53.2	47.5	100.7
Belle	35.5	6.0	41.5
Cabin Creek	20.9	-	20.9
Glasgow	53.9	-	53.9
Alloy	9.5	-	9.5
Totals	230.5	66.3	296.8

As determined in this emission inventory, the primary source of sulfur dioxide is coal combustion, which accounts for about 78 percent of the total sulfur dioxide emissions. Approximately 8,800 tons of coal are burned each day by industrial plants to provide steam and heat for chemical processing. Two electric utility plants (Cabin Creek and Glasgow) consume an additional 3,950 tons of coal per day. Natural gas is used for domestic and commercial heating, but it does not produce significant amounts of sulfur dioxide. The coal burned in the study area contains between 0.7 and 1.7 percent sulfur by weight.

Industrial process emissions account for about 22 percent of the total sulfur dioxide emissions. The sulfur dioxide emissions in South Charleston are about evenly divided between those due to coal combustion and those due to chemical processing. A large sulfuric acid plant and emergency combustion of gases containing sulfide, account for the majority of the industrial sulfur dioxide process emissions in this area. A similar situation occurs in Nitro where a single sulfuric acid manufacturing process accounts for over two-thirds of all chemical process emissions.

Since most of the sulfur dioxide emissions are due to industrial coal combustion and chemical processes, there is very little seasonal change in these emissions.

Relationship Between Emissions and Air Quality

Since only two areas in the Kanawha Valley exceeded air quality goals for sulfur oxides, reduction plans were developed only for those areas. The ambient air concentrations of sulfur dioxide are dependent upon the mass rates of sulfur dioxide emission, the concentration of sulfur dioxide in flue gases, the effective elevation of sulfur dioxide emissions, the location of sources of sulfur dioxide, and the diffusion capacity of the air basin. In order to attain air quality goals, all of these factors must be considered. Calculations made by NAPCA meteorologists take into account these factors and indicate the percent contribution to the air quality measurements of each major source in each area of concern.

In developing a reduction plan, the first step is to determine the percentage improvement in air quality needed to achieve the goals. This required improvement can then be translated into specific source reduction plans. The same percent of reduction in existing ambient air levels of sulfur dioxide needed to achieve the air quality goals is applied to determine the needed reduction in sulfur dioxide emissions. Sulfur dioxide in the atmosphere is essentially contributed by man-made activities and there is, therefore, no need to consider background levels.

Table 5-7 presents the results of these procedures. The air quality goal of 0.1 ppm over a 24-hour period was compared with the 99th percentile value of existing air quality. The goal allows for measurements to exceed 0.1 ppm 1 percent of the time during the year. The percentage improvement in air quality needed to meet the air quality goals was calculated as 38 percent in South Charleston and 41 percent in North Charleston, based on sampling conducted in 1964 and 1965.

Emission Reduction Plans

The annual emissions of approximately 109,600 tons of sulfur oxides are not evenly distributed throughout the study area, but are generally located in several small, highly populated areas. Sulfur dioxide emissions in the South Charleston area alone account for more than one-third of the total sulfur dioxide emissions in

Table 5-7. DETERMINATION OF PERCENTAGE IMPROVEMENT IN AIR QUALITY REQUIRED TO MEET SULFUR DIOXIDE GOALS

Area exceeding goal	Air quality goal 24-hour average, 99 percent of time, ppm	Existing air quality, 24-hour average, 99th percentile values, ppm	Improvement needed, percent
South Charleston	0.1	0.16	38
North Charleston	0.1	0.17	41

the study area. The emissions from the South Charleston industrial area also affect the air quality of the highly populated North Charleston area.

Alternate emission reduction plans will be presented for the two areas of concern. The plans are based on diffusion calculations made by NAPCA meteorologists. The calculations indicate the relative contribution of each major source of sulfur dioxide to the ground-level concentrations measured in the source area.

The required reductions in sulfur dioxide emissions in the two specified areas, based on present-day technology, can be achieved by either reducing emissions from chemical process stacks or burning a lower sulfur fuel.

The emissions of sulfur dioxide from contact sulfuric acid plant absorbers can be reduced by improving the conversion efficiency of sulfur dioxide to sulfur trioxide and absorbing the sulfur trioxide to produce additional acid, or by removing the sulfur dioxide with alkaline scrubbers.

The following reduction plans for the two areas having concentrations of sulfur dioxide that exceed the air quality goals are based on emission estimates. Detailed information on production rates and conversion efficiencies of sulfuric acid plants and on the operation of process flares was not available. Estimates on conversion efficiencies for contact sulfuric acid plants were, therefore, based upon information contained in PHS Publication No. 999-AP-13, entitled "Atmospheric Emissions from Sulfuric Acid Manufacturing Processes." Alternate reduction plans should provide a reasonable basis for making decisions on sulfuric dioxide reductions from specific sources.

North Charleston - Air quality measurements of sulfur dioxide in North Charleston indicated that a 41 percent improvement in air quality is needed to meet the stated goals. Alternate reduction plans for emissions of sulfur dioxide were developed based on meteorological calculations of the relative contributions from various major sources located in South Charleston. The results for North Charleston are shown in Table 5-8.

Table 5-8. NORTH CHARLESTON REDUCTION PLANS FOR EMISSIONS OF SULFUR DIOXIDE, FOR FOUR SOURCES

Source	Relative contribution of SO_2 emissions to measured ground-level concentration, percent[a]	Needed reductions of source emission of SO_2, percent		
		Plan 1	Plan 2	Plan 3
South Charleston				
Source No. 1				
Coal-burning plant	1	0	0	0
Source No. 2				
Coal-burning plant	12	0	0	100
Source No. 3				
Coal-burning plant	6	0	0	100
H_2SO_4 Absorbers and concentrators	59	70	55	25
Source No. 4				
Coal-burning plant	6	0	0	100
H_2S flare	16	0	100	100

[a] Based on meteorological diffusion estimates.

Emission reduction plan No. 1 involves increasing the conversion efficiency of the sulfuric acid plant to 98 percent and controlling sulfur dioxide from acid concentrators. Alternate plan No. 2 increases the conversion efficiency of the sulfuric acid plant to 97 percent and requires a complete reduction in sulfur oxide emissions from the hydrogen sulfide flare. Alternate plan No. 3 would eliminate sulfur dioxide emissions from coal burning and from the hydrogen sulfide flare. Other plans could be developed which would achieve an overall sulfur dioxide reduction of about 41 percent.

South Charleston - Air quality measurements at South Charleston show that a 38 percent improvement in air quality is necessary to meet the stated goals. Meteorological diffusion calculations indicated that the sulfuric acid plant and acid concentrators were the principal contributors to high ground-level concentrations of sulfur dioxide in South Charleston. Consequently, the use of plan No. 1 for North Charleston should also result in achieving the air quality goals in South Charleston, since the same site location is involved.

Impact of Proposed Reduction Plans on Existing and New Emissions

If source emissions of sulfur dioxide from South Charleston are reduced to recommended levels, the air quality goals should be met in the Kanawha Valley area.

Concentrations of sulfur dioxide in other sections of the valley are presently close to the air quality goals, however. Continuing ambient air measurements for sulfur dioxide should be made to determine if further reductions are needed after the recommended source reductions have been effected in South Charleston. Additional ambient air measurements for sulfur dioxide and other sulfur compounds should be made in the Nitro area to further investigate the high sulfation and metals deterioration results, especially at the site west of Nitro.

The proposed emission reduction plans are based only on current emissions. Expansion of source emissions from existing installations in South Charleston or added emissions from new installations in the valley would require very restrictive emission limits for sulfur dioxide. New potential emitters of sulfur dioxide should be located in areas where existing ambient air levels of sulfur dioxide are well below the air quality goals. Where feasible, sulfur oxide emissions from existing sources should be reduced through either installation of control equipment, process modification, or fuels modification.

Since completion of the field study, one sulfuric acid plant in South Charleston has discontinued operations (Table 5-8, source No. 3). The impact of this marked reduction in sulfur oxide emissions should have a significant effect on air quality in North and South Charleston.

ODORS

Two odor surveys by high school students and odor patrols by the study staff, as reported in Section IV, indicate that objectionable odors are a serious air pollution problem in the Kanawha Valley, affecting most of the study area. A regulation on odors was developed and adopted by the West Virginia Air Pollution Control Commission as a result of these surveys. The survey procedures explained in Section IV were also the basis for the odor reduction plan.

Air Quality Goals

The air quality goals are limited to those considered to be "objectionable" odor or odors. An odor is considered to be "objectionable" when "in addition to those odors generally recognized as being objectionable, it is in the opinion of a duly authorized representative of the Air Pollution Control Commission, based upon his investigations or his investigations and complaints, that such odor is objectionable."

Thus the air quality goals are:

No "objectionable" odor at any location occupied by the public.

Odor Reduction Plan

The odor regulation promulgated by the West Virginia Air Pollution Control Commission designates the Barnaby-Cheney Scentometer or another similar instrument designated by the Commission as a tool or guide in the enforcement of the regulation and also in determining the objectionableness of an odor. By the inclusion of Section 2.02 in the State regulation, it is implied that continuing odor patrols should be used in the Kanawha Valley to enforce this regulation.

Comparison of emissions reported in the emission inventory with odorous compounds "generally recognized" as being "objectionable" could be used in the initation of control of sources of these odorous pollutant emissions. Priorities for the control of sources could be developed, using the above data as well as the results obtained by the odor patrols.

The recording and cataloging of complaints of objectionable odors could be used as an indicator of the effectiveness of the control program. While complaints may not point out the most serious odor problems, they are a measure of the effect of odorous pollutants on the public and point to sources of odorous emissions possibly not reported in the emission inventory.

Maintenance of a current emission inventory plus continuing analysis of complaints and the results of surveys by odor patrols should provide the means of measuring the success of the reduction program for odorous emissions. This will also lead to a continuing review of program priorities, and, if needed, a periodic reassessment of the control program.

Industrial, institutional, educational, and governmental organizations should be encouraged to conduct investigations of the relationship between their own production or the emission of objectionable odorous pollutants and their effects on the sense of smell of the public. Significant findings in this area would enable the development of regulations for the control of odorous pollutants on a fully instrumented or scientific basis.

HYDROCARBONS

Hydrocarbons are discharged to the air from a variety of sources in the Kanawha Valley. Principal sources are chemical processes and gasoline-powered vehicles which contribute 31.3 and 30.9 percent, respectively, of the total hydrocarbon emissions. Other sources include open burning of refuse, evaporation losses of organic chemicals and gasoline, and minor amounts from combustion of fuels for heat and power generation.

The primary importance of hydrocarbon and other organic chemical emissions is their participation in atmospheric photochemical reactions that produce ozone and other oxidants. Some hydrocarbons and organic chemicals are also important because of their obnoxious odors. Measurement of oxidant concentrations, taken during 1964 and 1965 and detailed in Section IV of this report, indicated that there was no photochemical air pollution problem in the Kanawha Valley Study Area at that time. However, predictions of hydrocarbon emissions and control status to the year 1980 are included in the emission reduction plan so as to evaluate future photochemical air pollution potential.

Air Quality Goals

Air quality goals, as such, are not prescribed for hydrocarbons. As noted previously, it is primarily total oxidants in the atmosphere that cause harmful effects and are of primary concern. The air quality goal for total oxidant of 0.1 ppm, by the potassium iodide colorimetric method of measurement has been suggested as a maximum permissible 1-hour average concentration. A study was made beginning in the fall of 1964 and continued during 1965 to determine oxidant concentrations at various locations. The results of this study indicated the possibility that some oxidants were emitted from certain chemical processes as well as being photochemically produced.

Existing Air Quality

Total oxidants were measured at six sites during 1964 and 1965 by a continuous colormetric analyzer on the U.S. Public Health Service mobile laboratory. Maximum hourly concentrations varied from 0.01 ppm to 0.41 ppm at North Charleston. North Charleston was the only location where the goal of 0.1 ppm oxidant concentration was exceeded. The data are summarized in Section IV. It should be noted that the high oxidant measurements were recorded after dark, during the spring and late fall. Therefore, it is reasonable to conclude that these oxidant measurements are not related to formation of photochemical air pollution but rather to chemical process oxidant emissions as indicated in more detail in Section IV.

Existing and Projected Emissions

Existing Emissions - The study area contains nine major chemical complexes and also numerous viscose rayon, synthetic rubber, and other small chemical plants. Over 60 million gallons of gasoline were consumed in 1964. About 145,410 tons of refuse was burned in 1964. Approximately two-thirds of this amount was open-burned, releasing excessive amounts of hydrocarbons. Other sources of hydrocarbon and organic gaseous emissions include gasoline evaporation, solvent evaporation, and industrial process losses. Estimated quantitative emissions of hydrocarbons are reported in Table 5-9. As indicated, 31.3 percent is emitted from industrial processes; 30.9 percent from mobile sources; 22.3 percent from refuse disposal, especially open burning; 12.3 percent from gasoline and solvent evaporation; and 3.2 percent from fuel combustion for space heating and power production.

Table 5-9. EMISSION OF UNCONTROLLED HYDROCARBONS PROJECTED TO 1980 IN THE KANAWHA VALLEY

Source class	Present emission, ton/year	Projected emission, ton/year
Fuel combustion		
Steam and heat generation	2,135	4,270
Transportation (mobile sources)	17,580	35,900
Industrial (inorganic and organic processes)	17,815	35,600
Refuse disposal	12,689	18,000
Gasoline and Solvent Evaporation	8,640	19,000
Total	58,892	112,770

Projected Emissions - Emissions of hydrocarbons from the above mentioned sources in the Kanawha Valley are projected to 1980 in Table 5-9. Emission of total hydrocarbons, based on current control measures, is estimated to increase proportionately with gasoline consumption, industrial expansion, and population growth to an estimated annual emission of 112,770 tons in 1980. This is an increase in emissions of hydrocarbons of approximately 100 percent over the 1964 estimate. This could have a significant effect on deteriorating the air quality in Kanawha Valley. It is expected that the emission control measures planned for automobiles and elimination of open burning will preclude a significant increase in the present ambient air levels of hydrocarbons.

Relationship Between Air Quality and Emissions

As indicated earlier, the primary importance of hydrocarbon emissions is in relation to the formation of photochemical air pollution as measured by the oxidant indicator. Combustion products from automobiles and other sources participate in atmospheric photochemical reactions that produce ozone and other oxidants. A study has indicated that the concentration of photochemical secondary pollutants is directly proportional to the concentration of the primary pollutants.[2] Thus, if oxidant precursors, including both hydrocarbons and nitrogen oxides, are reduced by the same amount, then oxidant concentrations will likewise be reduced proportionately. If the primary reactants are reduced in varying amounts, however, there is insufficient data to indicate the degree of reduction in oxidants. Because photochemical air pollution is not a problem currently in the valley, there is no apparent need to make such calculations. Section V, therefore, presents projected emission reduction plans for hydrocarbons emitted by mobile sources and refuse disposal.

Projected Emission Reduction Plan

Existing and projected hydrocarbon emissions have been established. Existing air quality data does not indicate a photochemical air pollution problem. An anticipated doubling of hydrocarbon emissions by 1980, however, is expected to have a detrimental effect on air quality in the Kanawha Valley. The purpose of this section is to consider the reduction in emissions which will occur as a result of control measures planned for motor vehicles and by elimination of open burning. Some decrease in 1980 projected emissions from industrial sources is also expected due to improved technology and installation of control equipment to control odors. However, it is not possible to estimate quantitatively the reduction in hydrocarbon emissions from the information presently available. The same can be said for gasoline and solvent evaporation losses. No reduction is anticipated in minor hydrocarbon emissions from fuel combustion for steam and heat generation.

Transportation - Transportation sources, if uncontrolled, are projected to emit 35,900 tons of hydrocarbons per year in the study area in 1980. Fortunately a program to control motor vehicle emissions is in progress at the national level. Public Law 89-272 authorized the Secretary of Health, Education, and Welfare to set limitations on air pollutant emissions from motor vehicles. Current regulations issued by the Secretary require complete elimination of crankcase blowby emissions beginning with 1968 model automobiles. Hydrocarbon emissions from the exhaust of 1968 model cars are limited to 275 ppm by volume, measured as hexane. Proposed 1970 standards were published in the Federal Register, Volume 33, January 4, 1968. They would limit exhaust hydrocarbon emissions to 2.2 grams per mile, which is roughly equivalent to 180 ppm by volume for the standard-size car. This is a reduction of approximately 80 percent in hydrocarbon emissions from an uncontrolled vehicle. The proposed 1970 standards would also limit evaporative hydrocarbon losses to 6 grams per test, which is estimated to be a 90 percent reduction in current evaporation losses. In this 12-year period, from 1968 to 1980, there will be almost a complete turnover in automobiles on the road. By 1980, most automobiles will be equipped with air pollution control devices. If the proposed 1970 standards are promulgated and the present automobile population remains constant, the overall reduction in automotive hydrocarbon emissions will be about 85 percent. The hydrocarbon emission rate from transportation sources would be reduced to approximately 6,400 tons per year in the Kanawha Valley.

Refuse Disposal - In 1980, refuse disposal sources are projected to emit 18,000 tons of hydrocarbons per year, based on current disposal practices. Proposed elimination of open burning, to reduce particulate and odor emissions, will also substantially reduce hydrocarbon emissions. The proposed elimination of single-chamber incinerators will also reduce hydrocarbon emissions. If all refuse is disposed of by either sanitary landfill or in properly designed and operated multiple-chamber incinerators, the overall reduction in hydrocarbon emissions would be about 99 percent, and estimated hydrocarbon emissions from refuse disposal in 1980 would be about 150 tons per year.

Impact of Proposed Reduction Plan on Emissions

Table 5-10 presents projected hydrocarbon emissions to 1980 based on the above planned control measures. As noted earlier, industrial sources and gasoline and solvent losses are expected to be reduced somewhat but no quantitative estimate of this reduction can be made with presently available data. In any case, anticipated hydrocarbon emissions from automobiles and incineration will be reduced to about 65,470 tons per year in 1980. This is comparable to current emission rates and thus should preclude a photochemical air pollution problem in the Kanawha Valley.

Table 5-10. HYDROCARBON EMISSIONS PROJECTED TO 1980
BASED ON PLANNED CONTROL MEASURES
(tons/year)

Source class	Present emissions	Projected emissions, no control	Projected emissions, with controls
Fuel combustion			
Steam and heat generation	2,135	4,270	4,270
Transportation	17,580	35,900	6,400
Industrial	17,845	35,600	35,600
Refuse disposal	12,689	18,000	200
Gasoline and solvent evaporation	8,640	19,000	19,000
Total	58,892	112,770	65,470

CARBON MONOXIDE

Carbon monoxide is emitted primarily from motor vehicles. Consequently, emissions and ambient air concentrations are generally related to traffic pattern, both by time and location. Automotive emissions must be reduced if major reductions in ambient air contentrations of carbon monoxide are to be achieved.

Air Quality Goals

A maximum 8-hour average concentration of 30 ppm carbon monoxide and a 1-hour average concentration of 120 ppm have been proposed as the air quality goals for the study area by the Joint Study Technical Committee. These goals may require revision when more comprehensive air quality criteria are published by the U.S. Department of Health, Education, and Welfare.

Existing Concentrations

Ambient air concentrations of carbon monoxide were measured at six sites in the Kanawha Valley. The downtown Charleston site was selected to determine what was considered to be the maximum effect on air quality of carbon monoxide emissions from vehicles. The Nitro, North Charleston, Marmet, and South Charleston sites were selected principally to determine the effect of industrial emissions of carbon monoxide on the air quality of areas normally considered to be commercial and residential, yet affected by emissions from industrial sources. The Kanawha City site was selected because it is a commercial and residential area with no immediate sources of industrial emissions. The sampling was conducted for 1-month periods during the several seasons of the year so that seasonal variations in concentrations of carbon monoxide could be determined.

The proposed air quality goal of 120 ppm for a 1-hour average concentration was not exceeded at any sampling site. Hourly concentrations of carbon monoxide greater than 30 ppm occurred on only two occasions and were measured at the South Charleston site. The greatest 24-hour concentration, i.e. 16.1 ppm, also occurred in South Charleston. Concentrations of carbon monoxide greater than 22 ppm occurred 1 percent of the time that measurements were conducted in Charleston during the winter, in South Charleston during the fall, and North Charleston during the spring. At the Charleston, North Charleston, and South Charleston sites, concentrations greater than 9 ppm appeared 10 percent of the time that measurements were made. Concentrations greater than 9 ppm occurred less than 1 percent of the time at Kanawha City, Marmet, and Nitro.

From a comparison of existing concentrations of carbon monoxide in the ambient air with the proposed air quality goals, it may be concluded that emissions of carbon monoxide do not presently constitute a significant air pollution problem in the Kanawha Valley. It should be worthwhile, however, to estimate the projected emissions of carbon monoxide to 1980 to evaluate the future air pollution potential.

Existing and Projected Emissions

Based on an emission inventory conducted in Kanawha Valley in 1964, there are 102,352 tons per year of carbon monoxide emitted into the atmosphere. Transportation, the principal source of carbon monoxide emissions, is responsible for 90,704 tons per year, or 88.6 percent. Gasoline-powered road vehicles account for 96 percent of the carbon monoxide emissions in the transportation category. Industrial processes and combustion of fuel for industrial heat and power contributed 6.0 percent and 4.7 percent respectively of the total emissions.

Areas of major source emissions in order of magnitude are Charleston, Belle, South Charleston, and St. Albans. Because several of these areas are not significant industrial sites, the measured concentrations of carbon monoxide are more indicative of emissions from high density vehicle traffic than from industrial sources.

Projections indicate that by 1980, the rate of gasoline consumption in the Kanawha Valley will approximately double the present rate. If emissions from automobile exhausts continue to be uncontrolled, the emitted carbon monoxide would increase proportionately to about 180,000 tons per year in 1980.

Emission Reduction Plan

The uncontrolled emissions of carbon monoxide in automobile exhaust gases are approximately 3.1 percent by volume under average urban operating conditions. Starting with the 1968 model automobiles, the limitations on carbon monoxide emissions have been specified by Federal law at 1.5 percent by volume for all vehicles with an engine displacement in excess of 140 cubic inches. The overall reduction in emissions achieved by these controls would be about 50 percent. This should result in ambient air concentrations of carbon monoxide in 1980 essentially the same as the present levels.

The Federal government will require that emissions of carbon monoxide be controlled to 1.0 percent by volume starting with 1970 model automobiles. If the emission limitation is applied to all automobiles by 1980, the overall carbon monoxide emissions in 1980 should be about 35 percent, lower than present levels.

NITROGEN OXIDES

An emission reduction plan for nitrogen oxides, as such, is not included in this report. The primary reason for this omission has been the lack of air quality criteria, which in turn makes the setting of air quality goals for this class of pollutants impractical. Also, control technology for nitrogen oxides is limited for most combustion sources. Whenever air quality standards are prescribed, emissions of nitrogen oxides and the resulting ambient concentrations of these pollutants will need to be evaluated, reductions in these emissions will have to be prescribed, and measures will have to be taken to achieve the reductions. As a first step in the design of such an emission reduction, nitrogen oxide emissions are related to the various types of sources and estimates of future emissions are given.

By far the most important source of nitrogen oxides is the combustion of fuels. The increasing population and the continuous urbanization of the study area will undoubtedly result in higher energy requirements. These requirements, at least in part, will be fulfilled by increased consumption of fossil fuels, which will, unless controlled, increase the emissions of nitrogen oxides.

Existing Concentrations

Nitrogen dioxide concentrations were measured in the study area beginning in the fall of 1964 and ending in the winter of 1965, with several mobile laboratory units. The seasonal arithmetic mean concentration of nitrogen dioxide during this period, using a continuous analyzer, varied from 0.03 to 0.16 ppm. The maximum 1-hour average concentration during this same period was 0.44 at the Post Office in Nitro during the fall of 1964 and the sampling site at Kanawha City during the winter of 1965.

Comparison of observed concentrations with the State of Colorado air quality standard, which is 0.1 ppm for 1-hour for greater than 1 percent of the time in any 3 months, was exceeded at all of the sampling locations. The California standard of 0.25 ppm for 1-hour was exceeded in South Charleston, Nitro, and Kanawha City. Potential photochemical smog, related to nitrogen dioxide concentrations does exist.

Existing Emissions

During 1964, an estimated total of 56,067 tons of nitrogen oxides was released to the air of the study area. Various source categories accounted for the following percentages of the total area emissions: Industrial heat and power, 61.5 percent; electric power generation, 25.7 percent; transportation sources, 9.1 percent; industrial processes, 2.2 percent; and other sources, 1.5 percent.

Stationary Combustion Sources - During 1964, an estimated 49,623 tons of nitrogen oxides was emitted from the combustion of fuels in stationary sources. The combustion of coal accounted for 92.5 percent, natural gas for 4.4 percent, and chemical process residues for the remainder of 3.1 percent. During the same period coal supplied 60 percent; chemical process residues, 28 percent; and gas, 12 percent of the energy requirements. These figures are based on a total heat input of 22×10^{13} Btu.

The projected fuel consumption from stationary sources for the study area is listed, by user category, in Table 5-11. Projections for 1980 indicate an increase, above the 1964 consumption levels, of almost 65 percent in the use of coal and 40 percent in the use of gas, and a 37 percent decline in the use of fuel oil. The overall increase in the energy to be supplied by these fuels was estimated to be approximately 37 percent.

Table 5-11. PROJECTIONS OF FUEL CONSUMPTION IN KANAWHA VALLEY STUDY AREA

Fuel	User category	1964	1980
Coal, tons/yr	Utility	1,411,020	4,300,000
	Industry	3,152,463	3,310,000
	Commercial, institutional, and residential	11,094	3,950
	Total	4,604,550	7,613,950
Fuel or chemical process residues, gal/yr	Utility	Negligible	Negligible
	Industry	41,003,000	29,900,000
	Commercial, institutional, and residential	250,000	183,000
	Total	41,253,000	30,083,000
Natural gas, 10^6 ft^3/yr	Utility	Negligible	Negligible
	Industry	13,981	19,400
	Commercial, institutional, and residential	11,439	16,020
	Total	25,420	35,420

A change in fuel-use patterns is expected to accompany the increase in total energy requirements. In the case of the residential use of fuels for space heating, an increase is projected in the use of gas and electricity whereas coal and fuel oil consumption is expected to decline. In the industrial category, fuel oil consumption is projected to decrease, with the consumption of coal increasing about 5 percent. Consumption of coal by the steam-electric utilities is projected to increase by 200 percent by 1980.

According to these projections, approximately 80,317 tons of nitrogen oxides will be emitted in 1980 from the combustion of fuels in stationary sources. This is 30,694 tons or 62 percent more than the 1964 emissions. The emissions from steam-electric utilities and industrial fuel use are expected to increase by 200 and 5 percent, respectively. The emissions of nitrogen oxides from commercial, institutional, and residential fuel uses are expected to increase by approximately 23 percent. Projected annual emission rates are summarized in Table 5-12 by type of fuel and user category.

Table 5-12. PROJECTIONS OF NITROGEN OXIDE EMISSIONS IN KANAWHA VALLEY STUDY AREA

	Emissions of nitrogen oxides, tons/year	
Source category	1964	1980
Combustion of fuels (stationary sources)		
Utility		
Coal	14,410	43,100
Fuel Oil		
Gas		
Industry		
Coal	31,525	33,100
Chemical process residues	1,476	1,078
Gas	1,496	2,090
Commercial, institutional, and residential		
Coal	44	16
Fuel oil	9	7
Gas	663	926
Total	49,623	80,317
Combustion of fuels (mobile sources)		
Automobiles	3,397	4,310
Diesel trucks	1,039	1,210
Other	687	815
Total	5,123	6,335
Industrial process emissions	1,240	1,440
Refuse disposal	81	174
Totals	56,057	88,266

Mobile Combustion Sources - During 1964, the estimated 103 million gallons of gasoline burned in the study area resulted in an emission of 3,397 tons of nitrogen oxides. An additional 1,726 tons was emitted by diesel trucks, and 687 tons by railroads, vessels, and aircraft. Unless controlled, the emissions of nitrogen oxides from motor vehicles would be approximately 4,310 tons per year by 1980.

Impact of Emissions

Nitrogen oxides constitute one of the five or six groups of major pollutants that originate community-wide and are of general importance. Population growth and its related activities in urban areas have caused the emissions of these pollutants to increase, and, unless controlled, the emissions will continue to increase.

The emission of nitrogen oxides from all sources is expected to increase slightly more than 57 percent by 1980, when approximately 88,267 tons per year will be released in the study area.

A reversal of the continually increasing nitrogen oxides emissions will be necessary, if not at the present then surely in the future. Ambient air sampling should therefore be continued to assess existing and future concentrations of nitrogen oxides. Similarly, investigation of control measures for reducing emissions from mobile as well as stationary sources should be encouraged.

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RECOMMENDATIONS

The following recommendations for continuing an effective emission reduction plan for air contaminants in the Kanawha Valley, West Virginia, are based on information and data contained in this report. Considerable progress has already been made in the prevention and control of air pollution as a result of this study. An example is the enactment of Regulations I through IV of the West Virginia Air Pollution Control Commission.

But the primary purpose of these recommendations is to stimulate the development of effective emission reduction plans for all major sources of air pollution in the Kanawha Valley. Recommendations are also given for monitoring and surveillance of sources and pollutants not currently shown to be air pollution problems.

Specific recommendations are:

1. Enacting the regulations outlined in this report to accomplish the particulate emission reduction plan and gain the following objectives.

   a. Limitation of total particulate matter from industrial process operation by the process weight concept as applicable to those industries located in the valley, incorporating the best process and control technology available.

   b. Limitation of sulfuric acid mist emissions to 35 mg/m^3 for new equipment and 70 mg/m^3 for existing equipment.

   c. Limitation of visible emissions from industrial process operations to No. 1 on the Ringelmann Chart or the equivalent opacity.

   d. Periodic review of the existing combustion particulate regulation to maintain its effectiveness in achieving present and projected goals.

   e. Elimination of all open burning including municipal, industrial and commercial, and domestic.

   f. Limitation of particulate emissions from incinerators to effect an overall reduction of about 90 percent of current levels.

   g. Limitation of visible emissions from incinerators to No. 1 on the

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Ringelmann Chart or the equivalent opacity.

2. Select and promulgate the appropriate sulfur dioxide emission reduction plan from the various alternatives presented in this report. Limit sulfur oxide emissions from both combustion and industrial process operations by requiring the use of low-sulfur coal produced locally, to prevent deterioration of existing air quality.

3. Implement a vigorous odor-control program.

4. Continue surveillance and monitoring activities initiated during the Study at selected sites of major concern:

   a. To monitor and update the particulate emission reduction plan.

   b. To assess the effectiveness of the sulfur dioxide emission reduction plan and to expand its application as emission rates increase.

   c. To evaluate the need for emission reduction plans for carbon monoxide and nitrogen oxides in the future and the effect of motor vehicle control systems required by Federal regulation.

5. Prohibit construction of certain types and sizes of industrial operations when air pollution control technology is inadequate when related to the limited ventilation in the valley.

6. Separate sensitive land use, such as housing, from areas of high air pollution potential in all community planning activities.

7. Enact regulations to require issuance of construction and operating permits from appropriate agencies to assure the installation and maintenance of effective air pollution control technology at each industrial and commercial source.

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APPENDICES

A. COOPERATIVE PROJECT AGREEMENT
KANAWHA VALLEY AIR POLLUTION STUDY

B. SUPPLEMENTARY METEOROLOGICAL INFORMATION

C. EMISSION FACTORS

D. INSTRUMENTS

E. DESCRIPTION OF FIXED SAMPLING STATIONS

APPENDIX A.
COOPERATIVE PROJECT AGREEMENT
KANAWHA VALLEY AIR POLLUTION STUDY

I. Title of project: Kanawha Valley Air Pollution Study

II. Cooperating agencies:

A. West Virginia Air Pollution Control Commission

B. U.S. Department of Health, Education and Welfare, Public Health Service, Division of Air Pollution

III. Project organization:

A. Joint Study Executive Council

The cooperating agencies, signatory to this project agreement, will jointly undertake a study of air pollution. They will be responsible for policy decisions, approval of finished reports and support of project operations.

A Joint Study Executive Council consisting of two representatives of each of the cooperating agencies will be responsible for administration and execution of the project. They are as follows:

1. Carl A. Lindstrom, United States Department of Health, Education and Welfare, Public Health Service, Regional Program Director for Air Pollution Activities, Region III.
2. Mario Storlazzi, United States Department of Health, Education and Welfare, Public Health Service, Division of Air Pollution.
3. N. H. Dyer, M.D., M.P.H., Chairman of the West Virginia Air Pollution Control Commission.
4. Carl G. Beard, II, Executive Director of the West Virginia Air Pollution Control Commission.

The Project Director will be the Executive Director of the West Virginia Air Pollution Control Commission.

B. Joint Study Technical Committee

A Joint Study Technical Committee is to advise the Joint Study Executive Council and the cooperating agencies on objectives of the project, conduct of the work and on periodic and final reports. The Committee will meet from time to time, on call of the cooperating agencies. The Executive Council will prepare an agenda and information documents for use of the Joint Study Technical Committee. This committee will be composed of one representative designated by each of the following:

1. West Virginia Air Pollution Control Commission (N.H. Dyer, M.D., M.P.H.).
2. Kanawha Valley Air Pollution Technical Advisory Council (Page Seekford, M.D.).
3. West Virginia University (Professor Benjamin Linsky, P.E., M.S.E.).
4. West Virginia Institute of Technology (Dr. L.C. Nelson).
5. Industries of the Kanawha Valley (Mr. A.C. Hyde).
6. USDHEW, Public Health Service, Division of Air Pollution (J. J. Schueneman).

C. Citizens Air Pollution Council

A Citizens Air Pollution Council, composed of representatives of various organizations and citizens having an interest in conservation of the air resources of the Kanawha Valley, will be organized by the Executive Council. The Citizens Air Pollution Council will be formed by invitation, nomination and recommendation. Its purpose is to provide a means whereby broad segments of the community will be informed on progress of the study and will have opportunities to make suggestions to the cooperating agencies concerning conduct of the study, findings and other pertinent subjects.

IV. Need for the project:

Technical studies and public expressions over more than a decade and existing air pollution activities indicate there is a desire on the part of residents of the Kanawha Valley for improvement of ambient air quality. An air resource management program should be developed which will provide for protection of the public health, safety and welfare, and for achievement of air quality desired by the residents of the Valley. The industrial character of the Valley is complex; this complexity is reflected in the varied types and numbers of pollutants emitted to the atmosphere. The air pollution problems are aggravated by the valley topography and meteorology which limit dispersion of pollutants, and tend to allow accumulation and persistance of pollutants in the Valley. A study of information and data accumulated in past investigations, together with data to be obtained in the present studies, will help provide a basis for air resource management activities.

Capabilities of various agencies and educational institutions for investigation of air pollution problems need to be further developed as a part of the State effort for air resource management.

V. Purpose of the project:

The purposes of the project are to evaluate the air pollution situation in the Kanawha Valley area and to assist in development of an air resource management program for the study area. It is expected that the study will help develop personnel and facilities for air pollution control work both within the project area and elsewhere in the State.

VI. Location of the project:

The joint study will be done in the Kanawha Valley area, generally extending from Gauley Bridge through the City of Nitro and its industrial environs. Although the basic study will be confined to the Valley itself, some studies may involve other areas for such purposes as meteorological measurements and ecological observations of vegetation.

Project headquarters will be located in the offices of the Executive Director of the West Virginia Air Pollution Control Commission in Charleston, West Virginia.

VII. Duration of the project:

Activities will be initiated on or about July 1, 1964. The project will continue for approximately two years.

VIII. Study activities:

The study will involve the following activities. The order of listing does not imply priority nor time of initiation. A preliminary work program, in greater detail, is in Appendix A.

A. Measurement of Air Quality

Measurements of air quality will be made at several sites which will provide the basic detailed air quality information required concerning common pollutants. A network of stations will be used for certain other measurements and special investigations. The distribution and number of stations will be based on availability of resources to operate them and the need for data.

B. Meteorology

Meteorological studies will include an analysis of climatological data and measurements of meteorological parameters of interest in describing the diffusion and transport of pollutants in the Valley. Existing local meteorological data will be obtained from weather stations at the airport and those maintained by several industries. Additional stations will be established as required.

C. Odor Studies

Studies will be conducted to define the geographic distribution, intensity and duration of odor occurrences. The studies will include reporting by groups of observers and patrols by trained observers.

D. Collection and Evaluation of Existing Information

Existing information relating directly and indirectly to the air pollution situation in the Valley will be collected and analyzed.

E. Pollutant Emission Inventory

An inventory of air pollutant emissions from residential, commercial, institutional, industrial and mobile sources will be made. Major single and group sources will be identified and located to provide general information on the various types of problems. The industrial emission inventory will be made with the cooperation and assistance of the industries of the Valley.

F. Effects of Pollution on Vegetation

Vegetation ecology studies to determine the effects of air pollution on vegetation in the Valley will be conducted. It is contemplated that this will be done on a contract basis.

G. Special Air Analyses

Within available resources, special studies and analyses will be made of particulate and gaseous pollutants resulting from specific operations of special significance and interest in the area. Such studies may be made by staff personnel and on a contract or grant basis.

H. Effects of Pollution on Health

Studies of possible effects of air pollution on health are highly desirable and are contemplated. Considerable effort will be made to arrange for such work. Implementation of actual work will depend on ability to design appropriate studies and to secure adequate funding and specialized personnel. Grants will likely provide the major portion of funds for these studies. Funds to make such studies are not provided for in this project agreement.

I. Means and Economics of Pollution Control

Studies may be made of available methods for control of certain pollutant emissions and the costs thereof. Such studies will be done for those sources for which necessary information is reasonably available and on the basis of priorities determined as the study proceeds.

IX. Reporting and release of information:

On a quarterly basis, brief summary progress reports will be prepared by the Executive Council for review, evaluation and comment by the cooperating agencies and the Joint Study Technical Committee.

On a periodic basis, progress reports will be prepared and presented to the Citizens Air Pollution Council and for use as public information. These reports will be approved by the cooperating agencies prior to release.

Preparation of the final report on the study will be the joint responsibility of the cooperating agencies. Cost of printing will be shared in proportion to the number of copies desired by each agency.

A program of public information and education will be undertaken as a continuing part of the activities of this study. Generally, public information material will be prepared and will be cleared by the Executive Council, in consultation with the public information offices of the cooperating agencies. Normally, release of public information relative to the study will be made through the Executive Director and the Chairman of the West Virginia Air Pollution Control Commission after consultation with the Public Health Service when reasonably possible. However, the Public Health Service and the Joint Study Technical Committee may release such information, as may be deemed necessary, after consultation with the Chairman of the West Virginia Air Pollution Control Commission.

Clearance of reports will be subject to pertinent requirements of the cooperating agencies.

X. Estimated budget (July 1, 1964 - June 30, 1965):

The following budget provides estimates of the approximate contribution of the cooperating agencies. Contributions will not be in cash but will be made in terms of personnel assignments, equipment, services, supplies, vehicles, etc.

A. Public Health Service, USDHEW

Personnel (1 meteorologist; 1 engineer - full time)	$20,000
Travel (Transfer of personnel and travel of supervisory and consulting personnel)	2,000
Transportation (Local - in study area) (1 auto)	3,500
Consultants and supervisory personnel (Part-time)	5,000

Utilities (for mobile lab)	1,000
Supplies	2,000
Equipment	$ 5,000
Mobile laboratory	no charge
Miscellaneous (Including data processing)	13,000
	$51,500
Contract - Vegetation Ecology Study	2,500
	$54,000

B. West Virginia Air Pollution Control Commission

Project Director (1/3 time)	3,500
Personnel (1 chemist; 1 engineer - full time)	14,200
Transportation (Local - in study area)	4,000
Laboratory and office space and utilities and furniture	no charge
Supplies	1,000
Equipment	6,800
Miscellaneous (Including electric power to operate air samplers)	500
	$30,000
Contract - Study of Major Combustion Plants	2,500*
Contract - Special air sample analyses	10,000*
	$42,500

A similar budget is contemplated for this project for the year July 1, 1965 to June 30, 1966. An appropriate budget for that year will be developed by the participating agencies in April 1965 or as soon thereafter as feasible.

XI. Special provisions:

This study is expected to proceed for two years and perhaps somewhat longer. However, continuation beyond the end of the current fiscal year (June 30, 1965) is contingent upon availability of funds.

The Public Health Service will provide machine data processing services, including reduction of strip chart records from pollution recorders to punched cards; preparation of other punched cards; and sorting and tabulating and electronic computer computations.

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*Contingent upon the Commission receiving a Public Health Service program grant.

The Public Health Service employees assigned to this project will remain under the annual and sick leave provisions of the Federal law. They will obtain approval of the Project Director on applications for leave. Applications will be forwarded to Chief, Technical Assistance Branch, DAP, PHS, as the officer authorized to approve leave. Public Health Service employees assigned to this project will work under the direct technical supervision of the Project Director.

Changes in this agreement may be made by mutual consent of the agencies signatory to this document.

8/5/64 Emil E. Palmquist
Date Emil E. Palmquist, M.D.
Regional Health Director
Public Health Service
Region III, Charlottesville, Va.

8/5/64 N. H. Dyer
Date N.H. Dyer, M.D., M.P.H.
Chairman, West Virginia Air
Pollution Control Commission

8/5/64 Schueneman for
Date Vernon G. MacKenzie, Chief
Division of Air Pollution
Public Health Service

COOPERATIVE PROJECT AGREEMENT
KANAWHA VALLEY AIR POLLUTION STUDY

WORK PROGRAM

A. Air Quality Measurements

1. PHS Mobile Air Sampling Laboratory

This laboratory will be operated for one month periods during each of the three seasons at four sites. Operations will begin in July 1964 and continue for one year. It will be located in heavily populated areas. This will provide detailed data on common air pollutants. Continuous, automatic recorders will measure:

- Total hydrocarbons
- Carbon monoxide
- Carbon dioxide
- Oxidants
- Nitrogen dioxide
- Sulfur dioxide

A continuous wind speed and direction recorder will be operated nearby or at the mobile lab, as will be a hygrothermograph.

Strip filter paper samplers will be used to measure soiling index and hydrogen sulfide. A high volume sampler will be operated on a 24-hour per sample basis.

Manual methods will be used to measure certain other pollutants as found appropriate for specific locations, insofar as possible within capabilities of available manpower. These measurements might include the following, or others:

a. Hydrogen sulfide. Methylene blue method.

b. SO_2, sulfate, total acid as H_2SO_4. For differential analysis, a combination of simultaneous and individual determinations by several methods are made on filtered and unfiltered samples, as follows:

   1. Sulfur dioxide by the West and Gaeke method.
   2. Total acidity by the hydrogen peroxide method.
   3. Sulfate by the turbidimetric method.

c. Aliphatic aldehydes. MBTH method (3-methyl-2-benzothiazolone hydrazone hydrochloride) (colorimetric).

d. Formaldehyde. Chromotropic acid method, (colorimetric).

e. Ammonia. Nessler reagent (colorimetric).

f. Carbon disulfide. Xanthate or diethylamine copper acetate method (colorimetric).

g. Amines.

h. Total sulfides.

i. Others, to be determined from pollutant emission estimates.

2. Routine Air Quality Monitoring Network

About twelve locations will be selected to represent air pollution levels to which people of the valley are exposed. Data will be collected for one year, beginning in August or September 1964. Measurements will include the following:

a. Dustfall. Dustfall collectors (gravimetric).
b. Sulfation rate. Lead peroxide candles (gravimetric or turbidimetric).
c. Suspended particulates. Hi-vol Air Sampler (gravimetric, spectrographic and trace analysis to be selected).
d. Soiling index. AISI Filter Tape Sampler (transmission photometry).
e. Materials deterioration. Fabrics, plaques of silver, iron, aluminum, zinc (visual, weight-loss, reflectance photometry).

Maximum possible use will be made of data already available from activities of the West Virginia Air Pollution Control Commission, industries and others.

(See also item G later herein.)

B. Meteorological Studies

Existing data from USWB and industrial weather stations will be used, along with data to be developed in this study, to describe the transport of pollutants in the study area. There is a weather station at the Charleston airport (USWB). Four or five wind speed and direction observing stations are being operated in the Valley by industrial firms. Supplementary measurements may include the following:

1. Airport station
    a. Atmospheric turbidity (sun photometer)
2. Additional stations (pending study of existing stations)
    a. Wind speed and direction (up to four locations)
    b. Temperature and humidity (up to twelve locations)
    c. Visibility (landmark technique - four locations)
    d. Atmospheric turbidity (about four locations)

    e. Photographic documentation (various locations)
    f. Time-lapse photography (various locations)
    g. Pilot balloon tracking (theodolite - various locations)
    h. "Natural tracer" studies (air analyses for specific, unique pollutants along with analysis of air flow information)

3. Surveillance of synoptic meteorological conditions related to community ventilation rates

C. Odor Studies

The following are the methods that will be used for the odor surveys:

1. Observer corps of groups such as high school students, firemen and/or teachers who record odors observed at about four specified times each day for two or three-week periods. If, at a later date, a public opinion survey is conducted, an attempt will be made to relate data from the public opinion survey to the odor survey data for the purpose of better defining "acceptable" or "reasonable" air quality with respect to odors.

2. Odor patrols of trained observers using such techniques as the scentometer and the "odor unit" method. Cooperation of industrial representatives will be encouraged for the purpose of making observations and investigations both inside industrial plants and in the surrounding community.

D. Collection and evaluation of existing information

Existing information relating to air pollution will be analyzed. This work will include the following activities:

1. Analysis of existing data on:
    a. Air quality
    b. Meteorology

2. General descriptive matter on the area including:
    a. Community characteristics
    b. Population trends - number and geographic distribution
    c. Fuel use patterns
    d. Industrial activity
    e. Refuse disposal practices
    f. Transportation
    g. Planning and zoning activities
    h. Economic, agricultural and industrial characteristics and trends

3. Description of local ordinances, state laws and enabling acts and governmental programs related to air resource management.

E. Pollutant Emission Inventory

An inventory of air pollutant emissions will be made in several parts in keeping with characteristics of the sources of pollution which exist in the study area.

1. Major industrial plants

There are about 12 major plants. A questionnaire will be designed to collect information. Industry will be requested to bear major responsibility for reporting with the study group reviewing and discussing reports with individual plants. Data on quantity of product and raw material used is said to be unavailable because of disclosure of information vital to the competitive position of the companies involved. The same is said to be true of a large part of the information on the processes used to produce various products. Principal information requested will be pollutant emissions and major products produced at each plant. Data for plants covering large areas will be requested on the basis of plant segments covering areas of about 2,000 feet on a side. A check-list of pollutants of major interest will be part of the questionnaire. Quantity of products produced will be reported in general terms such as "high tonnage," "low tonnage," "specialty item," and "experimental processes" if more definite information is considered confidential by the reporting industry.

An engineering appraisal will be made of each major coal-burning plant (twelve or so) to provide information on existing combustion and emission control equipment, fuels and operating practices. The objective will be to secure detailed information needed to design emission control regulations and to negotiate abatement programs. This may be done by a contractor.

2. Smaller industrial plants

A questionnaire of nominal complexity will be used to secure information on processes, practices and emissions from combustion and process and refuse disposal operations. A limited number of plant visits will be made to review information reported.

3. Commercial, domestic and institutional fuel use and refuse disposal

An attempt will be made to secure information needed to estimate emissions from trade representatives and generalized available data. If this is not adequate, a questionnaire survey may be needed.

4. Transportation and other sources

Generalized, available data will be used to estimate pollutant emissions from these kinds of sources.

F. Effects of Pollution on Vegetation

The work will involve a study of species of vegetation present in various parts of the area. This information, along with information on various aspects of the environment, may provide clues to the impact of air pollution on vegetation, on the geographic spread of pollution and, perhaps, on some characteristics of the pollutants present. Work will be done in the summer of 1964. Tentative plans include additional, similar work in the summer of 1965. The contract for this work is expected to provide for survey work both in the study area and in another area of interest in the state.

G. Special Air Analyses

A wide variety of uncommon pollutants are emitted from the multitude of chemical processes carried on in the Valley. Reactions may occur between pollutants in the ambient atmosphere. Definition and solution of some air pollution problems may well depend on precise knowledge of the composition of these unusual pollutants. Specialized methods of sample collection and analysis may be necessary. Some of these methods require use of expensive instruments and application of great technical skill. The cooperating agencies may not be in a position to bring necessary resources to bear on the problem and may find it advantageous to secure analytical services on a contract basis. Specific methods will be selected as information about pollutants is acquired in the joint study.

H. Effects of Pollution on Health

Description of work to be done awaits preliminary work in the study area. Also, specialized personnel must be interested in the problem and encouraged to design studies and secure financial support for their implementation.

I. Means and Economics of Pollution Control

The cost of equipment and its operation and other costs involved in achieving a given degree of control of pollutant emission is a factor in design of air pollution abatement programs. The more information there is available on this subject, the more advantageous will be the specific abatement plan. Necessary information is available with respect to such pollution sources as fuel and refuse burners and some others. It may be difficult to obtain with respect to unusual and unique industrial processes. Reasonable efforts will be made to secure the needed information. That which can be obtained will be considered in design of the air resource management program for the area.

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*Members who joined after July 1, 1964, are not included.

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APPENDIX B.
SUPPLEMENTARY METEOROLOGICAL INFORMATION

INSTRUMENTS

Wind Speed and Direction

In addition to several brands of wind recording instruments, which are listed by manufacturer or by trade name and described below, this section also covers the "Pibal" and "Tetroon" operation.

Aerovane - Bendix-Friez model 120 transmitter with six-blade rotor and model 141 recorders, and industrial instruments with three-blade rotors. The six-blade rotors were balanced on their transmitters by filing the heavy side of the rotor. The unit was then rotated about its normally vertical axis by gravity and balanced by adding weight to the tail through a 1/4-inch hole. As installed, these instruments had a starting speed of less than 2 mph and a distance constant of 34 feet. These instruments proved relatively insensitive to corrosion and dirt.

B and W - Beckman and Whitley model K 100 A utilizing Esterline Angus model AW recorders. When installed, the systems started at under 1 mph and had a distance constant of less than 3 feet. As corrosion and dirt accumulated in bearings, the starting speed approached 3 mph and the dirty bearing were replaced.

Electric Speed Indicator - The standard Weather Bureau Electric Speed Indicator instrument was read at hourly intervals by the duty observer at the Weather Bureau Station at the Kanawha Airport. Speeds below 3 mph were generally called calm.

ECO Wind II - This unit from the Wong Laboratories had a threshold speed of less than 3/4 mph and a distance constant on the order of 5 feet.

Other Instruments - A commercially operated Belfort instrument at station 70 had a starting speed of less than 2 mph. Another instrument at station 74 started at 3 mph. In data reduction, values below 2 mph were generally recorded as zero and directions were recorded to the nearest 10 degrees in most cases.

Pibal - Wind speed and direction were also measured by the pilot balloon or "pibal" method, which has been used extensively by all meteorological services for many years. The equipment used was standard in most respects. The pibal is a small balloon, about 30 inches in diameter when released. When inflated to lift a certain weight, the rate of ascent is known. A theodolite, similar to a surveyor's transit, is used to watch the balloon and determine at frequent intervals both the angular elevation above the horizon and the azimuth (bearing from true north). From the known height and the elevation angle, the distance from the observer can be determined. Using this distance and the azimuth angle, a horizontal projection of the balloon's path is plotted and the direction and speed of movement at any point are determined by measurements on the plotting board. In usual practice, position readings are taken at 1-minute intervals. For the purposes of this study, however, readings were taken at 20-second intervals in order to obtain more detail in the first few hundred feet of the atmosphere.

Tetroon - The "tetroon" is a four-sided plastic balloon. The plastic does not stretch as does the rubber in an ordinary balloon. Consequently, once the tetroon is fully inflated, the volume remains essentially constant, thus the overall density (tetroon and gas) does not change; and when released the tetroon seeks a level in the atmosphere where the density of the air is the same as that of the tetroon. The density can be controlled by using a mixture of air and helium for inflation and by attaching weights to the tetroon. Thus the tetroon can be made to float at a constant level near the surface or well above. The term "constant" is relative, since the tetroon responds to rising or sinking air currents as well as to horizontal currents.

Once released, the tetroon must be tracked in some manner. Although radar tracking of an inert target or of a transponder attached to the tetroon would have been preferred, no radar equipment was available for this study, and the tetroon had to be tracked visually. Terrain and lack of roads made tracking by use of an automobile difficult in the Kanawha Valley. The cooperation of the Air National Guard was obtained, and several tetroons were followed from the air.

Sunshine

Pyrheliometer - (Belfort Instrument Company A5-3850) This instrument consists of a clockwork-driven drum with a chart rotated against a pen mechanically linked to the radiation sensing element. The element is composed of two bimetallic strips, one blackened to absorb radiant energy and the other chrome-plated. The bimetal strips are covered by a Pyrex dome, which transmits 90 percent of all light waves from 0.36 to 2.0 microns, with ultraviolet cutoff at about 0.28 micron. Each line on the chart indicated 0.1 calorie per square centimeter per minute. During the period of observation, the chrome covers of the elements showed some corrosive pitting, especially on the instrument exposed in North Charleston, and so the chrome covers of the elements in both pyrheliometers were replaced and the blackened elements were reblackened. The instruments were exposed side by side for a period before the repairs were made. One instrument was then reconditioned and the two were again operated side by side for a period. The second instrument was then reconditioned, and the two were operated for another period side by side.

Before either instrument had been reconditioned, the Pyrheliometer numbered 22520 indicated 108 calories per square centimeter per minute when number 22519 indicated 100. After both instruments were reconditioned, the ratio was 101:100. In data reduction, these ratios were applied and the readings were made dimensionless by further reducing to comparison ratios with the airport being 100. Instrument 22519 was always used at the airport.

Volz Sun Photometer - (Climet Instruments, Inc.) The Volz sun photometer is a readily portable instrument, measuring about 2 by 2 by 6 inches and weighing under 1 pound, which measures solar radiation in the 5,000-Angstrom region. On cloudless days measurements of incident sunlight are adjusted for time of day, latitude, longitude, and elevation above mean sea level. The difference from standard is then attributable to pollutants in the atmosphere between the sun and the instrument. The effects of the above variables was minimized in this work by reading only near midday, by simultaneous readings of two instruments, and by keeping each instrument essentially at one elevation.

Temperature

Temperature data from existing U. S. Weather Bureau airport stations and river stations were augmented with available industrial readings. In addition, a temporary net of hygrothermograph stations was set up and free-air temperatures were measured in the tethersonde operation.

Hygrothermograph - This instrument records temperature and relative humidity. Practically identical instruments manufactured by the Instruments Corp., Belfort Instrument Co., or Friez Instrument Div. of Bendix Corp, were on hand and used. The temperature-sensitive element is a gold or chrome-plated bourdon tube; the humidity element is a multiple strand of specially treated, hygroscopic human hair. The sensors are mechanically linked to separate pens, which record on a single chart. Instruments were exposed in standard instrument shelters of the cotton-region type. Temperature records are considered representative of the ambient air, ± 1°F, and humidity values are accepted as ± 5 percent over most of the range of the instrument.

Tethersonde - The tethersonde is an adaptation of the radiosonde, an instrument that has been in wide-spread use for over 30 years. This instrument consists of a temperature-sensitive radio transmitter, which is carried aloft by a blimp-shaped plastic balloon (Aerokite of Litton Industries). The height to which this device ascends is controlled by a tether, hence the name "tethersonde". The transmitter sends a radio signal to ground equipment. The temperature sensor consists of a "thermistor," or small resistance element, which responds to changes in temperature and is aspirated by a small battery-powered fan. The unit also contains a humidity element and a switching device for cycling the transmitter between temperature, humidity, and reference elements. The electronic ground equipment consisted of a radio receiver, a converter for transforming the audio frequencies received into a voltage, a strip-chart recorder, and power supply for the radio and converter. The tether cord was 100-pound-test braided Nylon, which was marked at 50-foot intervals.

SITES AND DATA

Meteorological stations and instrument exposures are described in this section in the order encountered when descending the river. A brief station description precedes the tabulated data in each case. Locations are designated in Figure 2-1 and some of the stations are shown on photographs of the Charleston area in Figures B-1 and B-2.

Gauley Bridge

Station 50. River 650 feet MSL, hygrothermograph 658 feet MSL over grass and 25 feet from the New River, 1/2 mile up river from the junction of the New and Gauley rivers on the right bank. Prior to March 1965, instrument was located similarly but at the junction of the two rivers. The station operated from November 14, 1964 through March 31, 1966, Table B-1.

Smithers

Station 11. River 614 feet MSL, hygrothermograph 658 feet MSL over grass and 60 feet from the north bank of the Kanawha river at the Oakwood Elementary School in Smithers. This station operated from November 14, 1964, to March 31, 1966, Table B-2.

London Lock

Station 68. River 614 feet MSL becoming 590 feet MSL below the lock. Beckman and Whitley wind systems sensors at 655 feet MSL - 15 feet above 3rd gate support from north shore. Valley floor is narrow in the area and generally 20 feet above the pool behind the dam. The downstream valley direction changes abruptly from 300 degrees above the dam to 350 degrees below, and the walls are steep so that channeling is expected. Seasonal wind roses are included as Figure B-3. System in operation June 4, 1965 through May 31, 1966.

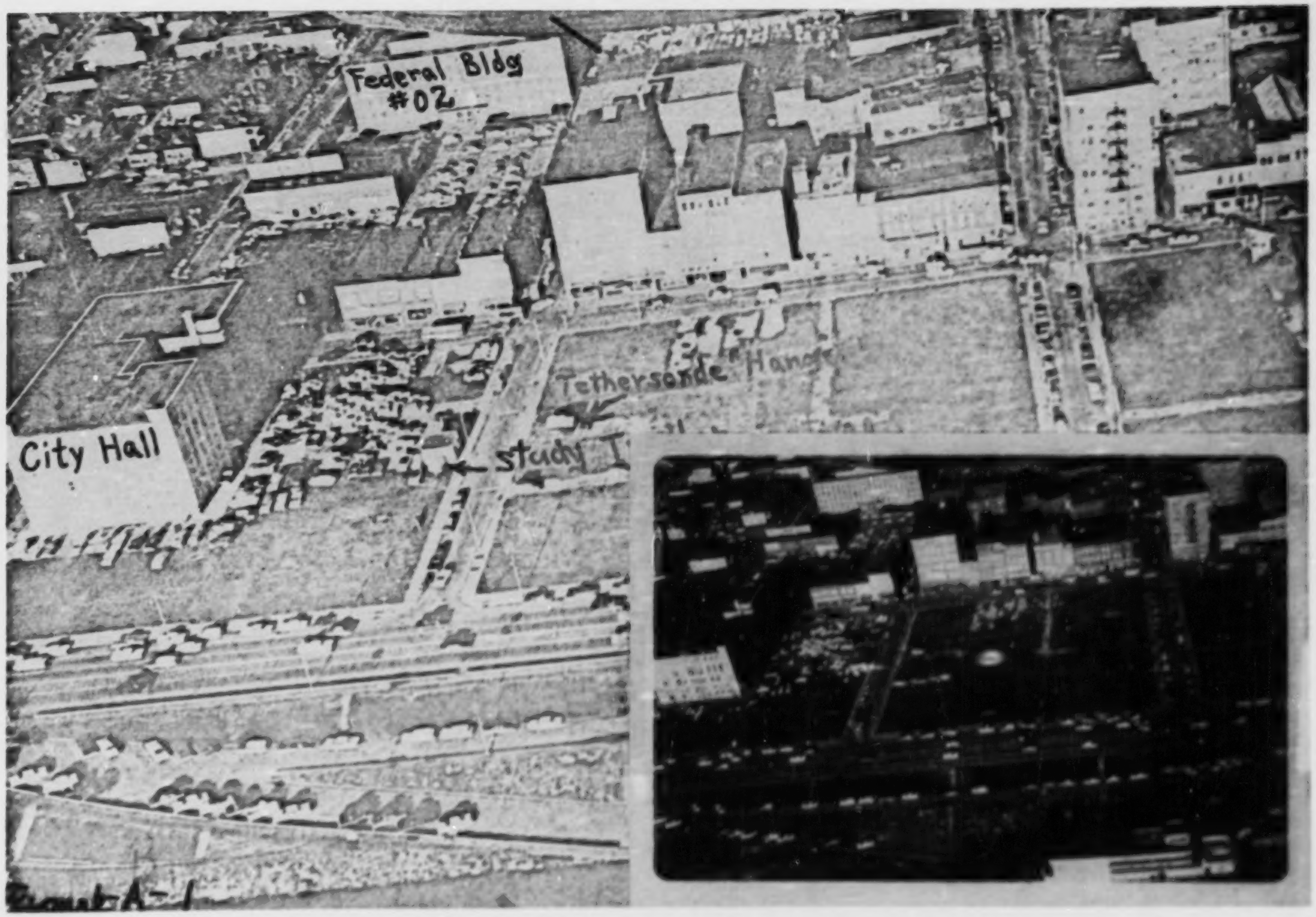

Federal Bldg
#02
City Hall
Tethersonde Hange
study I
Exhibit A-1

Figure B-1. City Hall in Charleston, W. Va. looking to north-east.

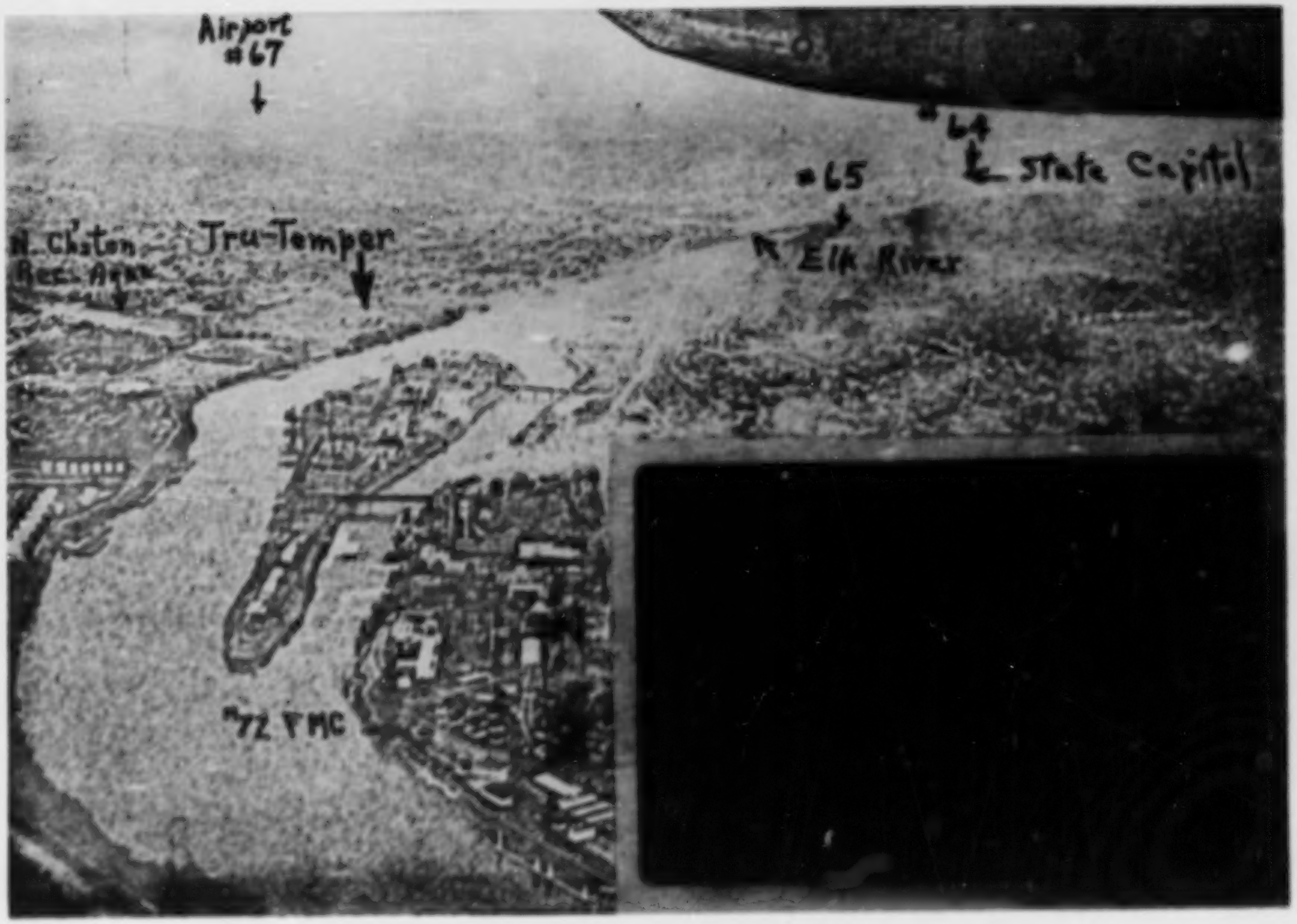

Airport
#67
#64
State Capitol
#65
Elk River
N. Ch'ston
Rec. Area
Tru-Temper
#72 FMC

Figure B-2. Blaine Island in Up-valley view of Charleston, W. Va. Spring and Fall Intensive Study Sites - Recreation Area. Summer - Tru-Temper.

Table B-1. TEMPERATURE AND RELATIVE HUMIDITY AT GAULEY BRIDGE

Hour LST	Spring 1965 1 Mar - 31 May			Summer 1965 1 Jun - 31 Aug			Fall 1965 1 Sep - 30 Nov			Winter 1964 - 1965 1 Dec - 28 Feb			Winter 1965 - 1966 1 uec - 28 Feb		
	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #
0	50.3	90.7	82	65.8	99.3	89	50.9	91.5	90	35.8	84.7	74	33.0	85.7	88
2	48.9	93.2	81	64.7	99.1	89	49.9	92.3	90	34.5	88.6	74	32.4	85.5	88
4	48.1	93.9	81	64.1	99.1	89	48.6	93.9	90	33.9	90.4	74	31.7	86.4	88
6	48.6	91.3	81	64.1	97.8	89	48.5	94.5	90	33.9	88.3	74	31.2	85.8	88
8	52.7	76.7	82	68.2	85.1	88	50.5	86.7	82	34.2	87.5	74	31.9	82.7	87
10	59.9	56.8	81	74.2	67.1	88	56.8	65.9	80	38.8	74.7	74	36.1	70.2	87
12	65.1	45.6	80	78.6	56.6	88	63.4	50.9	82	43.3	64.7	73	40.1	60.4	86
14	66.6	43.1	81	80.1	53.0	89	64.6	49.6	88	46.3	60.7	70	42.1	58.3	86
16	66.0	46.4	83	80.3	56.3	89	63.2	59.1	90	45.4	61.8	74	40.6	63.1	90
18	61.2	60.8	83	77.5	72.1	89	58.1	76.3	90	40.7	75.4	74	37.3	74.2	90
20	56.5	76.7	83	71.5	91.1	89	54.0	85.6	90	38.2	82.5	74	35.0	81.4	90
22	52.3	86.0	83	67.8	98.0	89	51.8	89.4	90	36.9	84.6	74	34.0	84.7	89

Table B-2. TEMPERATURE AND RELATIVE HUMIDITY AT SMITHERS

Hour LST	Spring 1965 1 Mar - 31 May			Summer 1965 1 Jun - 31 Aug			Fall 1965 1 Sep - 30 Nov			Winter 1964 - 65 1 Dec - 28 Feb			Winter 1965 - 66 1 Dec - 28 Feb		
	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #
0	49.1	86.9	92	65.3	95.4	87	52.0	89.6	90	34.9	82.4	90	34.2	83.5	89
2	47.4	90.1	92	63.9	96.6	87	50.9	90.8	90	33.8	84.0	90	33.5	84.2	88
4	46.5	91.7	92	63.3	97.0	87	50.7	91.6	90	33.3	86.2	90	32.8	84.9	88
6	45.9	92.3	92	62.8	97.2	87	49.6	93.2	90	33.1	86.3	90	32.3	83.9	88
8	48.4	87.2	92	65.0	91.8	87	50.3	91.5	85	33.2	86.6	90	31.9	84.8	88
10	56.3	69.0	92	72.2	74.2	87	57.6	73.7	80	36.7	79.2	89	35.2	77.9	88
12	62.2	55.8	92	78.6	61.5	87	64.4	57.7	88	41.9	67.7	90	40.4	65.4	88
14	66.2	50.1	90	81.2	57.5	87	67.4	52.6	90	45.2	62.8	86	43.1	60.5	87
16	65.4	50.0	92	82.1	57.1	87	65.4	56.3	91	45.0	62.3	90	42.3	61.5	89
18	61.7	55.4	92	78.9	65.8	87	59.9	70.8	91	40.6	71.7	90	39.0	70.8	89
20	56.2	72.1	92	72.2	83.7	87	55.2	82.5	91	37.7	79.6	90	36.6	77.3	89
22	51.5	81.4	92	67.7	90.9	87	53.0	86.8	91	36.5	81.1	90	35.5	81.8	89

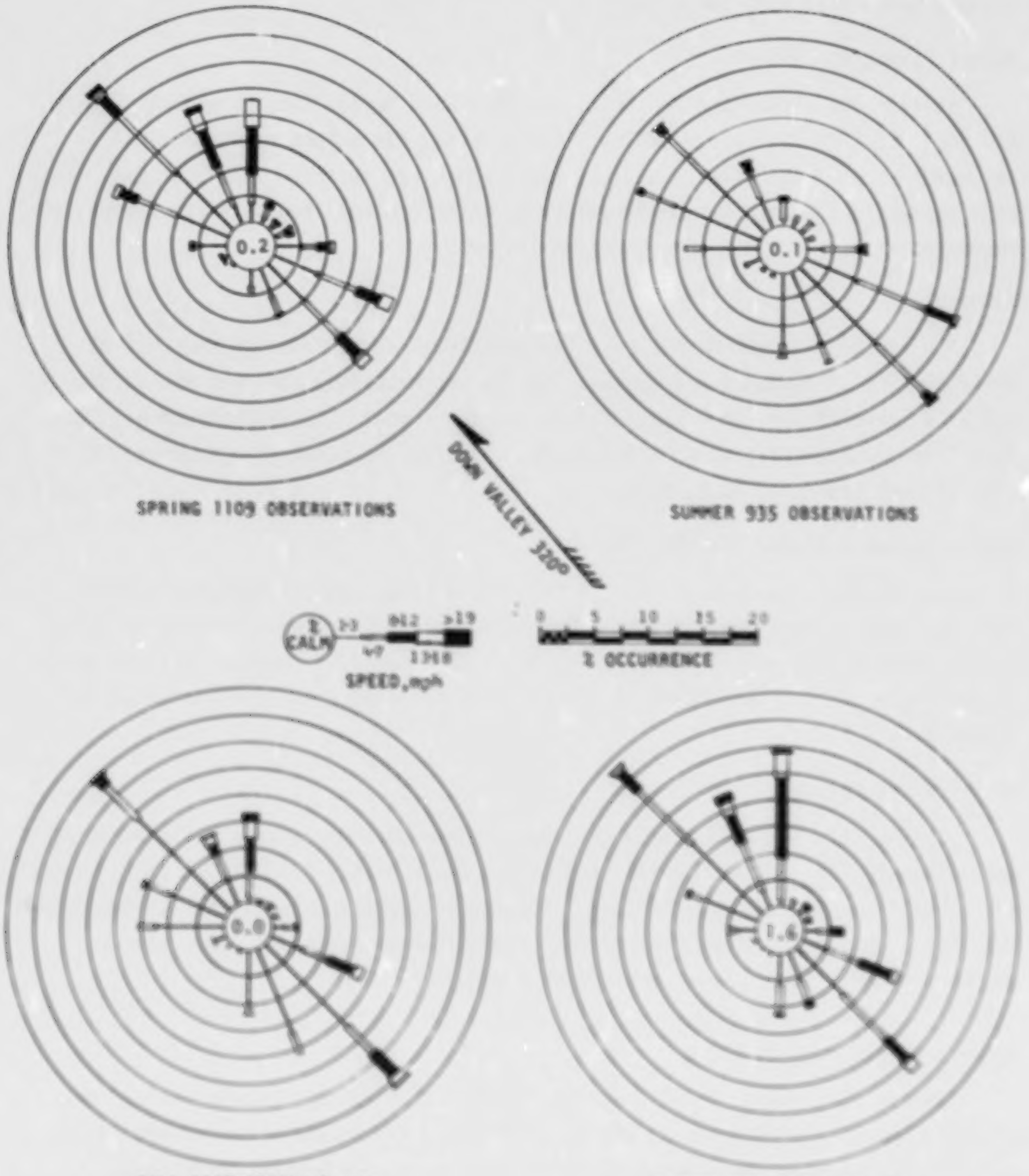


Figure B-3. London Locks.

Glasgow

Station 51. River 590 feet MSL, hygrothermograph 620 feet MSL over grass and 300 feet from the north bank. Instrument was in operation November 14, 1964 through March 31, 1966, Table B-3.

Dupont Plant, Belle Works

Station 70. River 590 feet MSL. Belfort wind system sensors approximately 810 feet MSL (200 feet above valley floor and near the height of the stacks) on the north side of the river. Seasonal wind roses are included as Figure B-4. This wind system is operated by the Dupont Corporation who supplied data for the period requested - March 1, 1965 through March 31, 1966.

Marmet

Station 52. At the Marmet Lock the pool level drops from 590 feet MSL to 566 feet MSL. A hygrothermograph was located approximately 610 feet MSL at the top of a steep grassy slope extending to the lower pool. The instrument was 100 feet from the southwest bank of the river. Data was recorded from November 14, 1964 through March 31, 1966, Table B-4.

Morris Harvey College, Kanawha City

Station 60. The sensors of a Beckman and Whitley wind system were mounted approximately 15 feet above the elevator penthouse on the administration building of the College. Sensors were estimated to be 680 feet MSL. System recorded winds between March 1, 1965 and March 31, 1966. Seasonal wind roses are presented as Figure B-5.

State Office Building

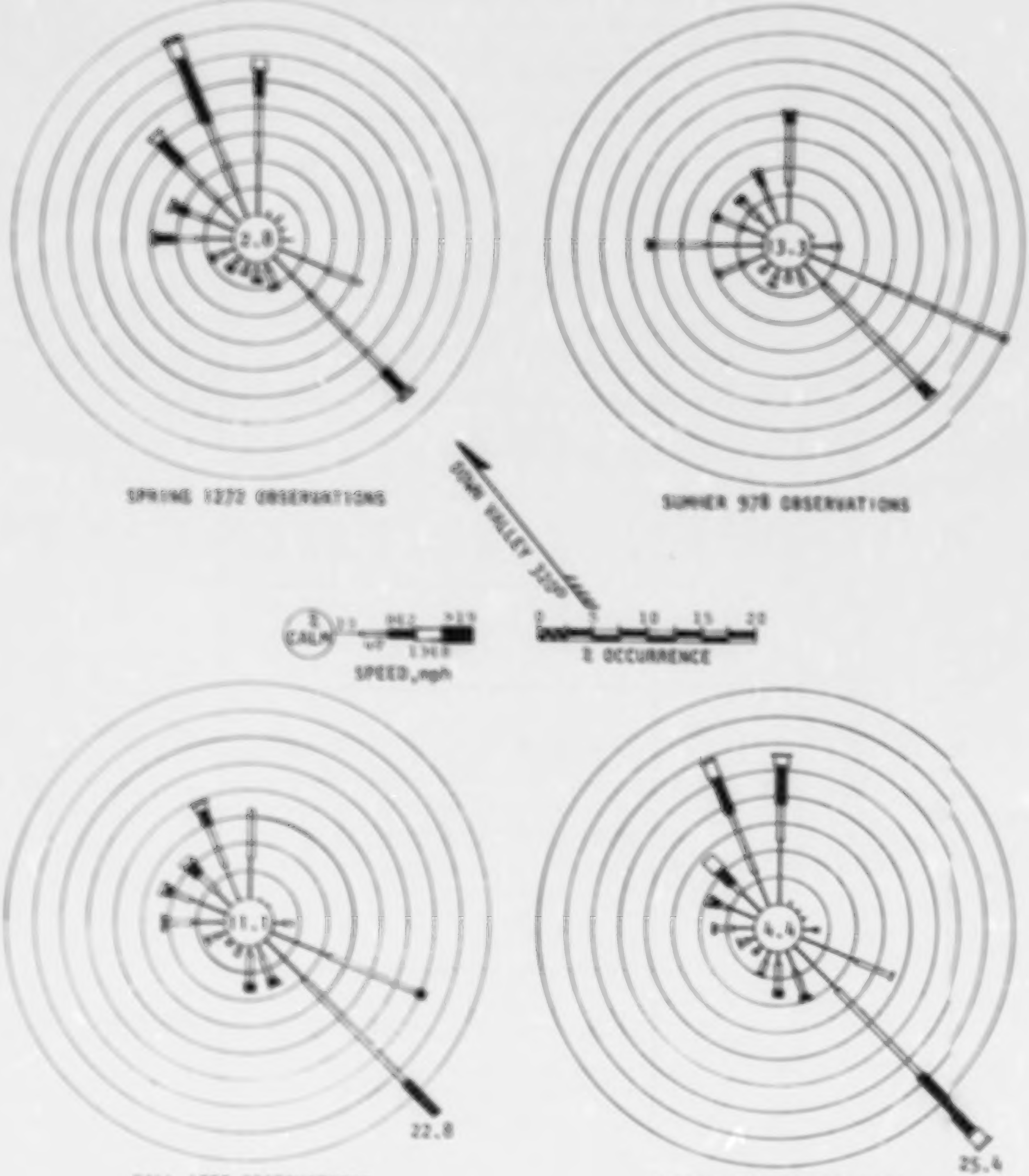
Station 64. The wind sensor of a three-blade aerovane system was mounted at approximately 675 feet MSL on the roof of the State Office Building which is across the river from Morris Harvey College. The sensor was estimated to be 110 feet above the river. Data period was from March 1, 1965 through March 31, 1966, and is graphically represented by wind roses in Figure B-6.

Kanawha Valley Bank Building

Station 63. A hygrothermograph on the main roof of the Kanawha Valley Bank Building was estimated to be at 800 feet MSL and 210 feet above the street, being held 8 feet out from the north side of an open ironwork tower on the building. Temperature and humidity data tabulated by season in Table B-5 cover the period December 15, 1964 through March 31, 1966 while the seasonal wind roses of Figure B-7 are based on wind data from March 1, 1965 through March 4, 1966.

Table B-3. TEMPERATURE AND RELATIVE HUMIDITY AT GLASGOW

Hour LST	Spring 1965 1 Mar - 31 May			Summer 1965 1 Jun - 31 Aug			Fall 1965 1 Sep - 30 Nov			Winter 1964 - 65 1 Dec - 28 Feb			Winter 1965 - 66 1 Dec - 28 Feb		
	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #
0	47.1	92.3	92	63.4	95.1	92	51.6	92.5	89	33.5	84.2	78	32.5	90.0	83
2	46.0	92.6	91	62.5	95.5	92	50.8	93.7	89	32.6	85.7	78	32.1	89.0	83
4	45.2	93.6	91	61.9	95.8	92	49.7	94.8	90	32.1	87.1	78	31.7	89.2	83
6	45.6	92.6	91	61.9	95.4	92	49.2	94.4	90	31.5	87.8	78	31.1	89.3	83
8	49.9	81.1	92	66.3	84.3	92	51.1	88.9	86	32.2	86.2	78	31.4	88.4	83
10	58.1	64.4	92	74.2	66.4	91	59.5	68.2	86	36.3	75.2	77	35.7	80.5	83
12	63.3	56.1	92	79.2	58.3	92	66.6	56.3	89	41.5	65.9	77	40.6	68.8	83
14	65.6	53.5	91	80.9	55.8	92	67.6	52.5	91	45.0	62.3	75	43.2	65.1	85
16	65.3	53.9	92	81.1	56.4	92	66.9	56.6	91	44.7	64.4	77	41.8	67.9	86
18	60.7	63.3	92	78.1	65.5	92	59.9	75.1	91	39.7	75.7	78	38.1	78.1	86
20	53.5	79.6	92	70.0	85.8	92	54.8	86.0	91	36.5	81.8	78	35.1	86.7	86
22	49.7	88.0	92	65.6	93.0	92	52.2	90.8	90	34.8	84.4	78	33.7	89.5	85



SPRING 1272 OBSERVATIONS

SUMMER 978 OBSERVATIONS

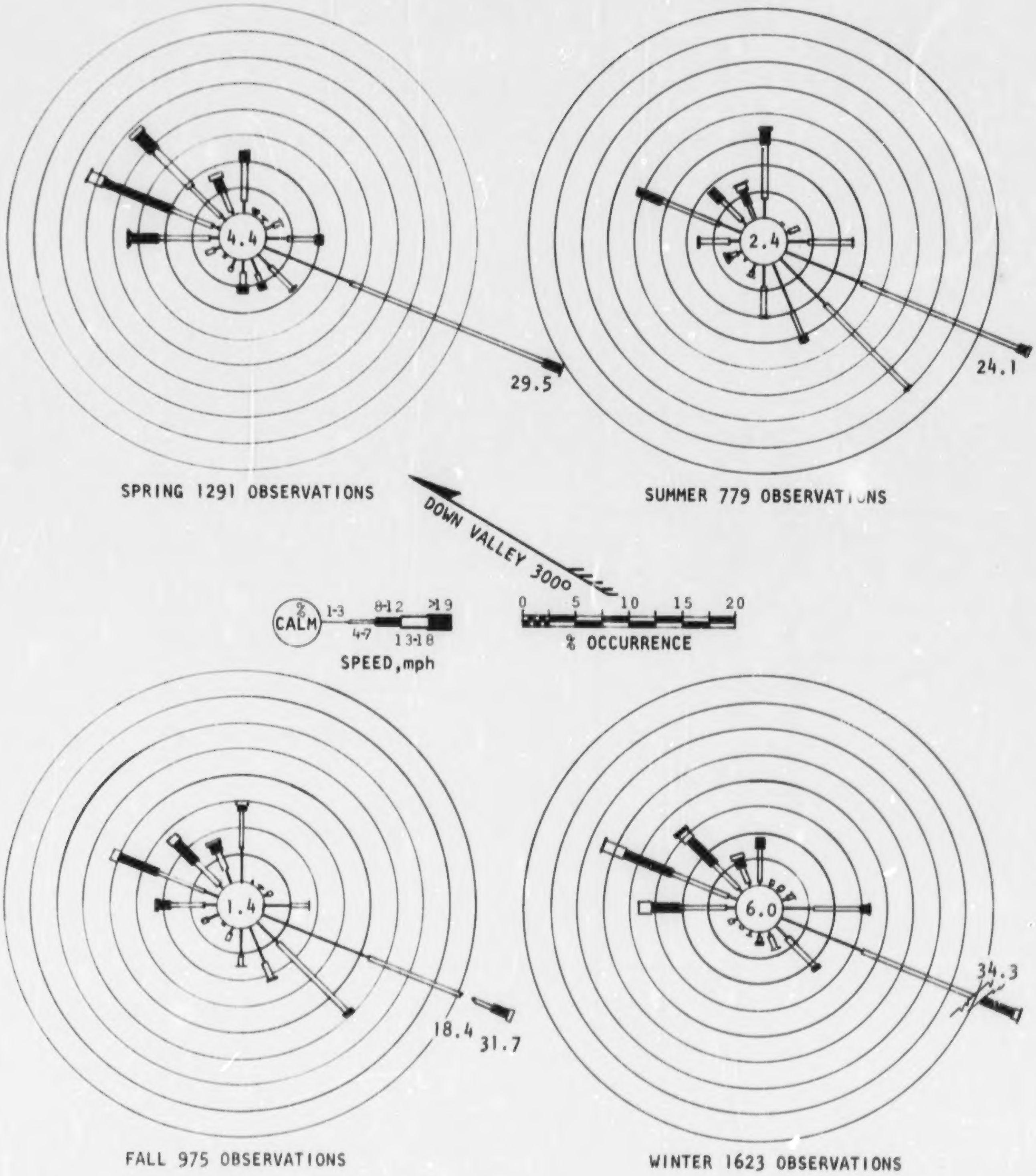
FALL 1755 OBSERVATIONS

WINTER 1715 OBSERVATIONS

Figure B-4. Dupont Plant, Belle Works.

Table B-4. TEMPERATURE AND RELATIVE HUMIDITY AT MARMET LOCKS

Hour LST	Spring 1965 1 Mar - 31 May			Summer 1965 1 Jun - 31 Aug			Fall 1965 1 Sep - 30 Nov			Winter 1964 - 65 1 Dec - 28 Feb			Winter 1965 - 66 1 Dec - 28 Feb		
	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #
0	48.7	89.9	92	64.2	99.0	92	52.8	91.5	89	34.5	84.2	88	32.5	89.0	86
2	47.5	93.1	91	63.0	99.3	92	51.1	93.7	90	33.6	87.5	88	31.9	88.5	86
4	46.6	94.4	91	62.1	99.4	92	50.0	94.9	90	32.8	87.7	89	31.1	90.2	86
6	46.0	94.7	91	61.8	99.6	92	49.4	95.4	90	32.4	89.2	89	30.1	90.9	86
8	48.5	87.2	91	66.0	91.0	92	50.5	92.9	88	32.6	87.8	89	30.7	89.3	84
10	56.0	66.5	91	74.4	66.2	92	58.5	69.4	88	36.6	78.8	86	34.7	78.7	84
12	61.7	53.8	91	79.0	56.4	92	65.0	52.7	90	42.1	65.0	85	39.5	64.5	86
14	63.9	50.2	91	80.5	53.1	92	67.3	48.9	90	44.5	61.3	82	41.8	60.2	86
16	63.8	51.6	91	80.6	53.8	92	66.2	52.0	91	44.6	62.8	84	41.0	61.9	87
18	60.7	59.3	92	76.5	65.6	92	59.7	71.5	91	40.4	74.7	86	37.5	72.8	88
20	54.9	75.2	92	69.4	89.5	92	55.5	83.8	90	37.3	81.0	87	35.0	83.4	88
22	51.3	84.7	92	66.2	97.2	92	54.1	88.7	88	35.9	84.1	88	33.7	88.4	87



SPRING 1291 OBSERVATIONS

SUMMER 779 OBSERVATIONS

FALL 975 OBSERVATIONS

WINTER 1623 OBSERVATIONS

Figure B-5. Morris Harvey College.

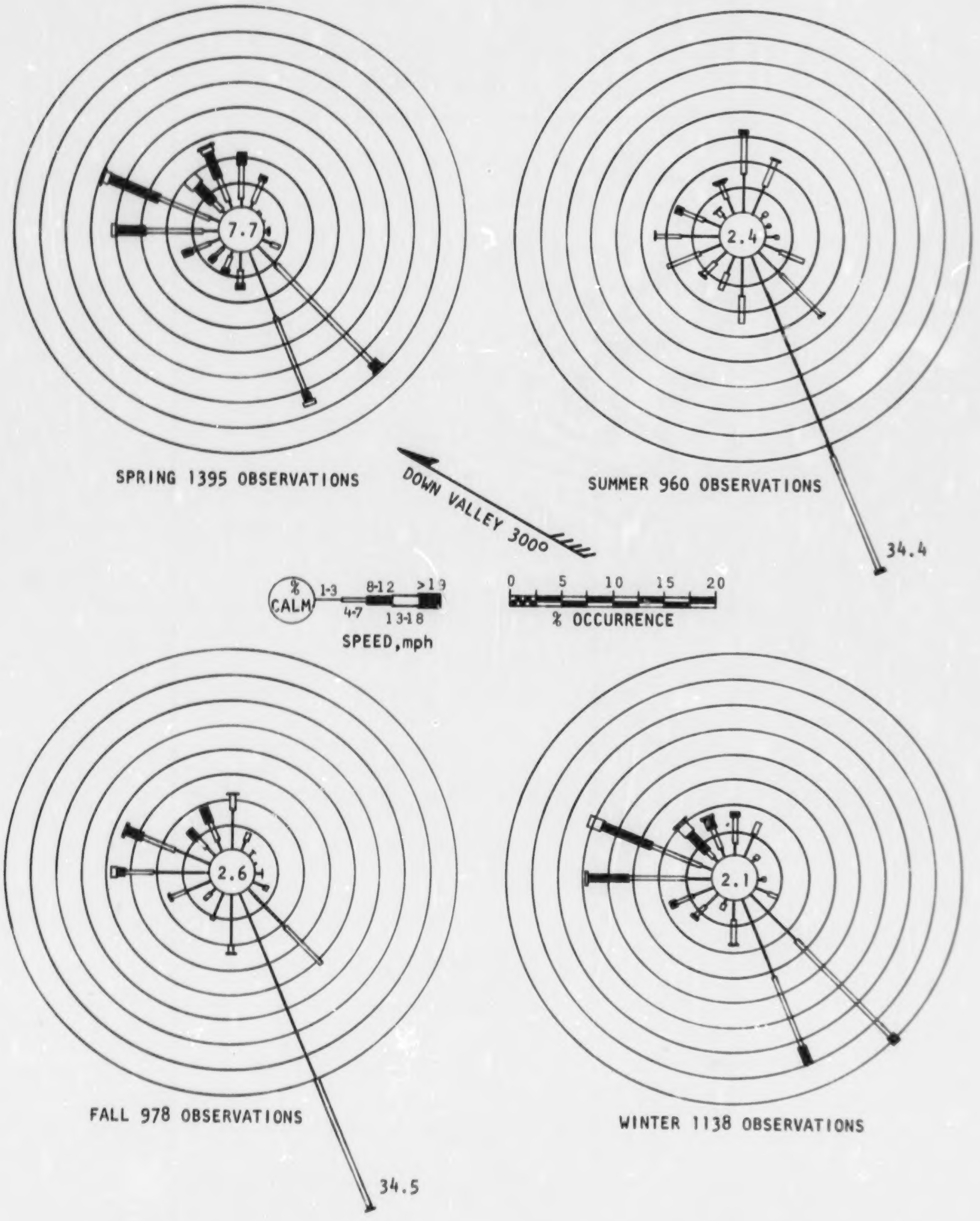
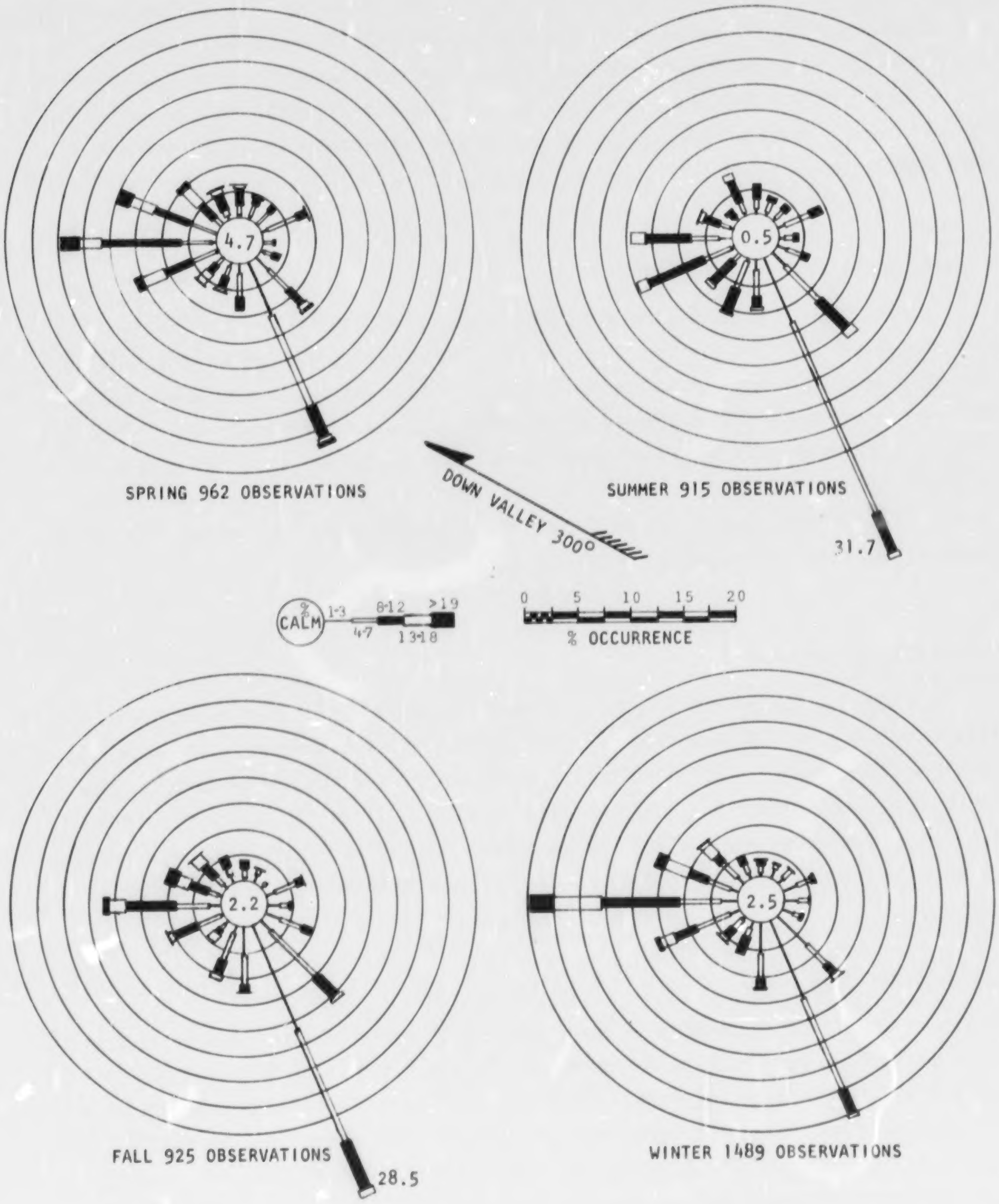


Figure B-6. State Office Building.

Table B-5. TEMPERATURE AND RELATIVE HUMIDITY AT KANAWHA VALLEY BANK BUILDING

Hour LST	Spring 1965 1 Mar - 31 May			Summer 1965 1 Jun - 31 Aug			Fall 1965 1 Sep - 30 Nov			Winter 1964 - 65 1 Dec - 28 Feb			Winter 1965 - 66 1 Dec - 28 Feb		
	Temp.[1] °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #
0	M	90.2	88	66.4	91.6	92	55.0	92.4	88	36.2	81.1	76	34.6	87.2	90
2	M	93.7	88	64.6	94.4	92	53.4	94.3	88	35.0	84.2	76	33.5	89.4	90
4	M	94.5	88	63.5	95.6	92	52.4	95.1	88	34.5	86.0	76	32.6	91.6	90
6	M	94.6	88	63.2	95.4	92	51.6	95.7	88	34.1	87.0	76	31.8	92.6	90
8	M	93.2	88	68.0	81.4	92	52.7	93.4	85	33.9	86.4	76	32.0	90.6	90
10	M	74.7	87	75.0	63.6	86	53.4	77.1	81	36.0	79.8	76	35.0	83.1	89
12	M	61.7	88	79.4	53.9	86	65.0	61.6	82	40.3	69.9	76	39.2	70.8	89
14	M	55.8	88	81.8	50.2	91	68.2	56.4	83	43.2	62.3	76	41.4	66.7	89
16	M	54.2	88	82.0	48.8	91	68.3	57.6	86	45.1	59.3	76	42.1	65.2	90
18	M	57.7	89	79.8	52.5	91	64.7	64.4	88	42.9	63.9	77	40.0	69.3	90
20	M	65.9	89	75.1	66.1	91	59.5	80.1	88	40.0	71.3	77	37.7	77.6	90
22	M	80.0	88	69.6	84.5	92	56.7	88.5	88	37.9	77.2	77	36.2	83.9	90

[1] Data missing.


SPRING 962 OBSERVATIONS

SUMMER 915 OBSERVATIONS

FALL 925 OBSERVATIONS

WINTER 1489 OBSERVATIONS

Figure B-7. Kanawha Valley Bank Building.

Federal Building

Station 02. The roof of the "New Federal Building" at 500 Quarrier Street East is 55 feet above the street so that the hygrothermograph in its shelter was 60 feet above street level. An ECO wind sensor was placed on a tower supported by the elevator penthouse being 20 feet above the roof or 660 feet MSL. Late in the study the ECO wind sensor was replaced with one manufactured by Raim. Hygrothermograph data in Table B-6 cover the period from November 21, 1964 through March 31, 1966 while the seasonal wind roses of Figure B-8 represent data between March 3, 1965 and March 31, 1966.

Charleston Water Treatment Plant

Station 53. The West Virginia Water Company has operated a cooperative climatological station for the U. S. Weather Bureau since 1944 and for this study a hygrothermograph was placed there. The instrument was exposed at about 580 feet MSL over grass just within the valley of the Elk River on the east bank. Shade from a cliff cover the instrument shelter for the first hour or so after sunrise and trees shaded the shelter in the early afternoon. Shelter was relocated about 20 feet during the summer of 1965 for better exposure. Table B-7 gives data between November 20, 1964 and March 31, 1966.

Kanawha County Airport

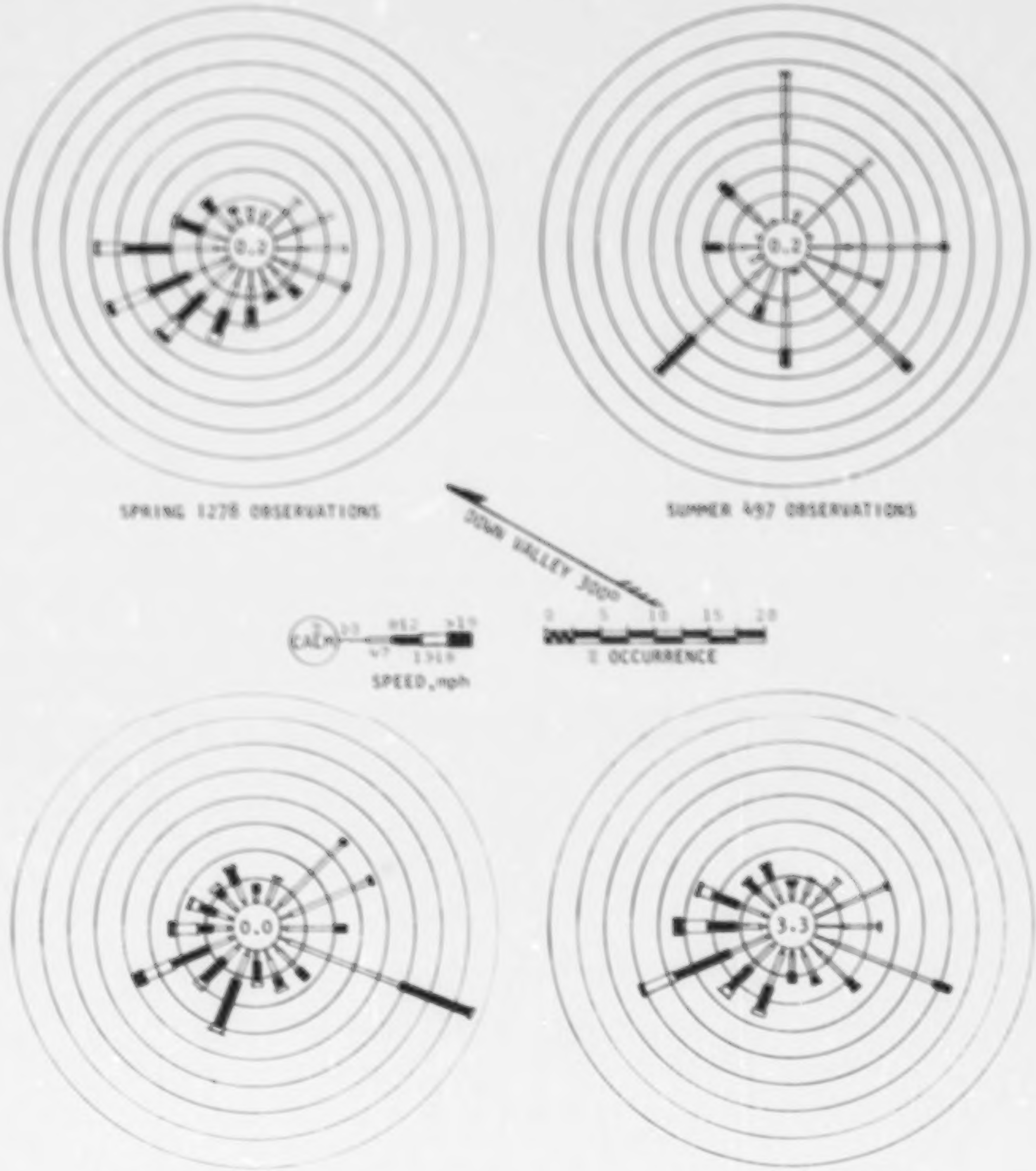
Station 67. Data from the U. S. Weather Bureau airport station represent a wind sensor within the runway complex at 985 feet MSL while temperature data are about 30 feet lower. A pyrhiometer was added to the station instrumentation for the study. Temperature and humidity data in Table B-8 are for the period December 1, 1964 through February 28, 1964; wind data presented as Figure B-9 are a 5-year climatic average, 1956-60, from official observation record.

400 Mountain View Drive

Station 65. This station on the south rim of the valley was 3.5 miles southwest from the airport and opposite the mouth of the Elk River. The sensors of a Beckman and Whitley wind system were mounted 50 feet above the hill, being estimated at 1,000 feet MSL while the instrument shelter was over grass in a generally shaded area at 945 feet MSL or 380 feet above pool level. Temperature and humidity data in Table B-9 begin on December 30, 1964 and wind data for Figure B-10 on March 9, 1965; both ending on March 31, 1966.

Table B-6. TEMPERATURE AND RELATIVE HUMIDITY AT FEDERAL BUILDING

Hour LST	Spring 1965 1 Mar - 31 May			Summer 1965 1 Jun - 31 Aug			Fall 1965 1 Sep - 30 Nov			Winter 1964 - 65 1 Dec - 28 Feb			Winter 1965 - 66 1 Dec - 28 Feb		
	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #
0	51.6	90.6	84	67.7	98.2	90	54.1	92.1	91	35.2	84.6	89	34.5	88.0	90
2	49.9	94.6	83	65.8	99.0	90	52.2	94.4	90	34.0	87.5	88	33.4	90.0	90
4	48.5	95.3	83	64.4	99.4	90	50.8	96.4	90	33.5	87.8	88	32.2	91.7	90
6	47.6	95.9	83	63.7	99.8	90	49.9	96.9	90	33.1	88.8	88	31.5	92.5	90
8	50.2	89.9	84	68.5	90.5	88	51.6	95.6	80	33.3	88.4	89	31.7	90.7	88
10	56.8	72.5	84	76.1	70.5	83	59.9	81.0	81	37.0	79.6	89	35.8	83.2	85
12	62.5	61.4	82	81.0	60.7	85	65.8	63.8	80	42.3	66.5	90	40.4	69.6	87
14	65.6	53.7	80	83.1	56.3	87	69.0	57.1	81	44.7	63.4	85	42.5	64.1	88
16	65.9	54.9	83	83.6	55.1	88	68.8	56.9	84	45.4	60.9	87	43.2	62.4	90
18	63.6	59.0	84	81.4	60.5	89	64.3	62.8	87	42.5	67.4	90	40.8	67.0	90
20	58.8	69.1	83	76.7	74.1	88	58.9	77.3	88	39.4	76.4	90	38.0	76.4	90
22	54.6	82.2	84	71.1	91.5	90	55.7	87.1	90	37.2	81.5	90	36.2	84.0	90



SPRING 1278 OBSERVATIONS

SUMMER 497 OBSERVATIONS

FALL 747 OBSERVATIONS

WINTER 1934 OBSERVATIONS

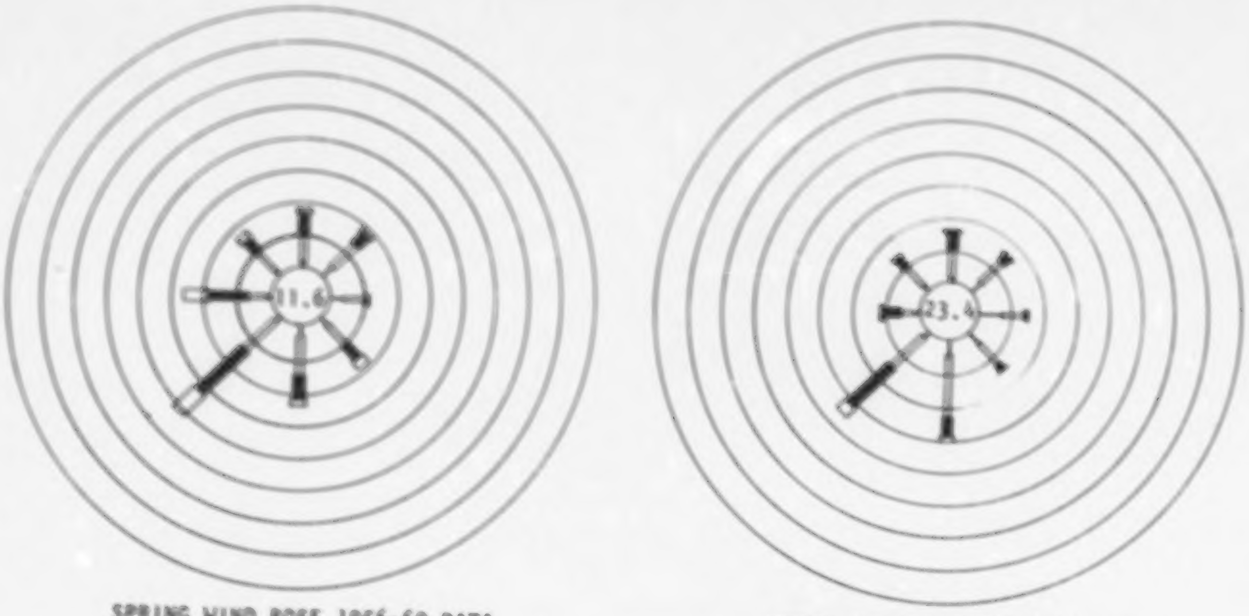
Figure B-8. Federal Building.

Table B-7. TEMPERATURE AND RELATIVE HUMIDITY AT CHARLESTON WATER TREATMENT PLANT

Hour LST	Spring 1965 1 Mar - 31 May			Summer 1965 1 June - 31 Aug.			Fall 1965 1 Sep - 30 Nov			Winter 1964 - 65 1 Dec - 28 Feb			Winter 1965 - 66 1 Dec - 28 Feb		
	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs #
0	47.3	91.0	87	64.0	98.1	88	51.8	92.7	91	33.4	86.8	83	30.3	91.0	86
2	45.7	94.0	87	62.4	99.3	88	50.4	94.6	91	32.4	90.2	83	29.7	90.6	86
4	44.4	94.3	86	61.3	99.7	88	49.2	95.2	91	32.0	89.7	83	28.7	92.0	86
6	43.8	94.6	86	60.6	99.7	88	48.5	96.0	91	31.8	91.2	84	28.0	92.2	86
8	47.4	86.6	87	64.1	92.7	85	49.4	94.5	88	32.0	89.6	84	28.3	90.6	85
10	54.6	66.2	87	71.7	71.4	83	57.6	71.5	82	36.7	79.5	84	33.5	80.0	83
12	60.4	54.5	87	77.3	57.8	82	65.7	53.3	85	42.9	64.8	84	38.9	66.9	85
14	63.3	49.3	86	80.3	51.8	84	68.6	49.1	88	45.2	61.5	79	41.0	61.8	84
16	62.8	50.2	88	80.3	52.0	89	67.3	50.7	91	45.2	61.1	81	41.2	60.1	86
18	59.7	54.8	88	77.5	57.3	89	61.3	65.8	91	40.4	72.3	84	37.1	71.1	87
20	53.6	72.4	88	72.0	77.8	89	55.9	84.0	91	37.0	82.9	84	33.9	83.2	87
22	49.4	84.9	88	66.8	93.4	89	53.2	90.0	91	34.9	86.1	83	31.9	88.5	86

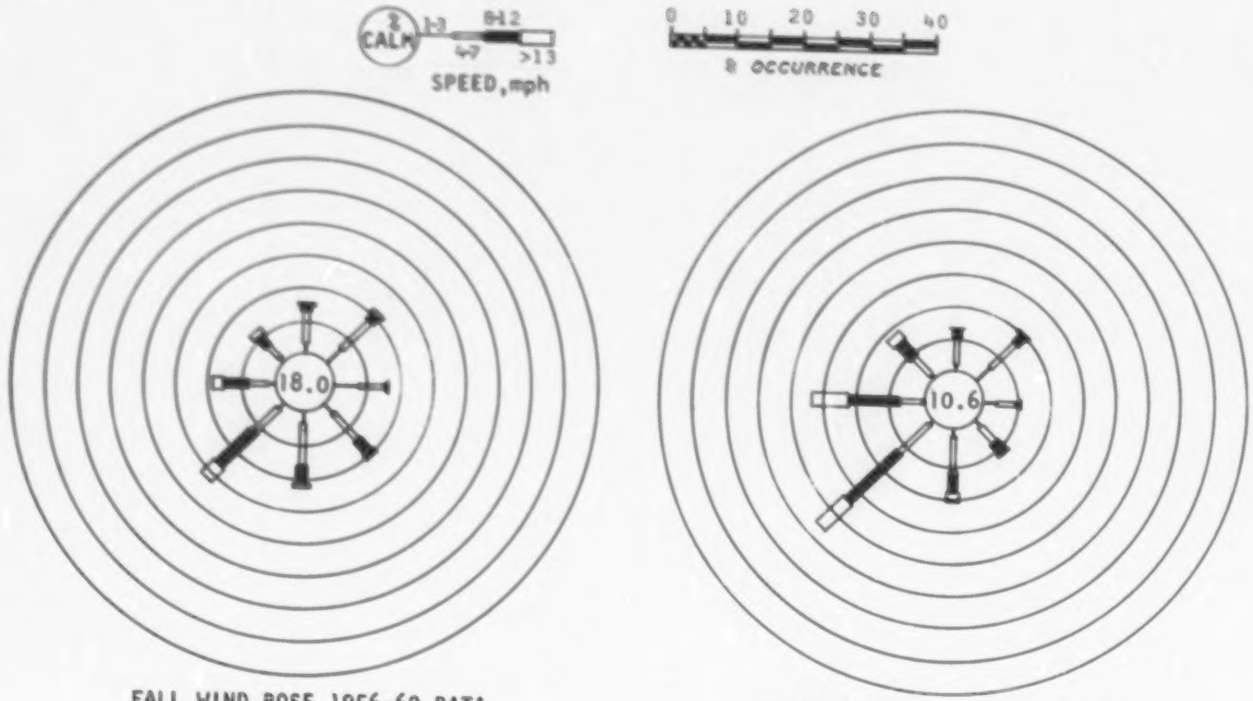
Table B-8. TEMPERATURE AND RELATIVE HUMIDITY AT KANAWHA AIRPORT

Hour LST	Spring 1964 1 Mar - 31 May			Summer 1964 1 June - 31 Aug.			Fall 1964 1 Sep - 30 Nov			Winter 1963-1964 1 Dec - 28 Feb			Winter 1964 1 Dec - 31 Dec		
	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #
0	53.6	67.4	91	67.3	85	92	51.0	73	91	30.2	73.1	60	33.8	76.3	31
2	51.3	71.7	91	65.4	88	92	48.9	78	91	28.7	74.7	60	32.9	77.4	31
4	49.5	76.1	91	64.2	90	92	47.9	80	91	27.8	76.1	60	32.6	78.3	31
6	48.8	78.1	91	63.5	91	92	46.1	83	91	27.0	77.7	60	32.2	79.7	31
8	53.0	69.9	91	68.4	83	92	47.6	81	91	26.5	78.2	60	31.5	81.2	31
10	59.1	58.2	91	76.5	65	92	56.5	63	91	29.2	74.8	60	34.8	77.5	31
12	63.0	51.6	91	81.0	54	92	64.1	47	91	33.7	64.3	60	39.3	68.7	31
14	66.0	45.7	91	82.8	51	92	67.4	42	91	36.0	59.4	60	41.8	63.4	31
16	66.6	44.0	91	83.2	48	92	68.0	40	91	37.1	56.2	60	42.7	61.6	31
18	64.7	47.1	90	80.6	53	92	63.5	48	91	35.7	59.1	59	40.3	66.7	31
20	60.3	55.1	91	75.2	67	92	57.5	59	91	33.2	64.7	60	37.3	73.5	31
22	56.8	61.3	91	70.6	77	92	53.6	67	91	31.4	69.5	59	35.7	74.7	30



SPRING WIND ROSE 1956-60 DATA

SUMMER WIND ROSE 1956-60 DATA



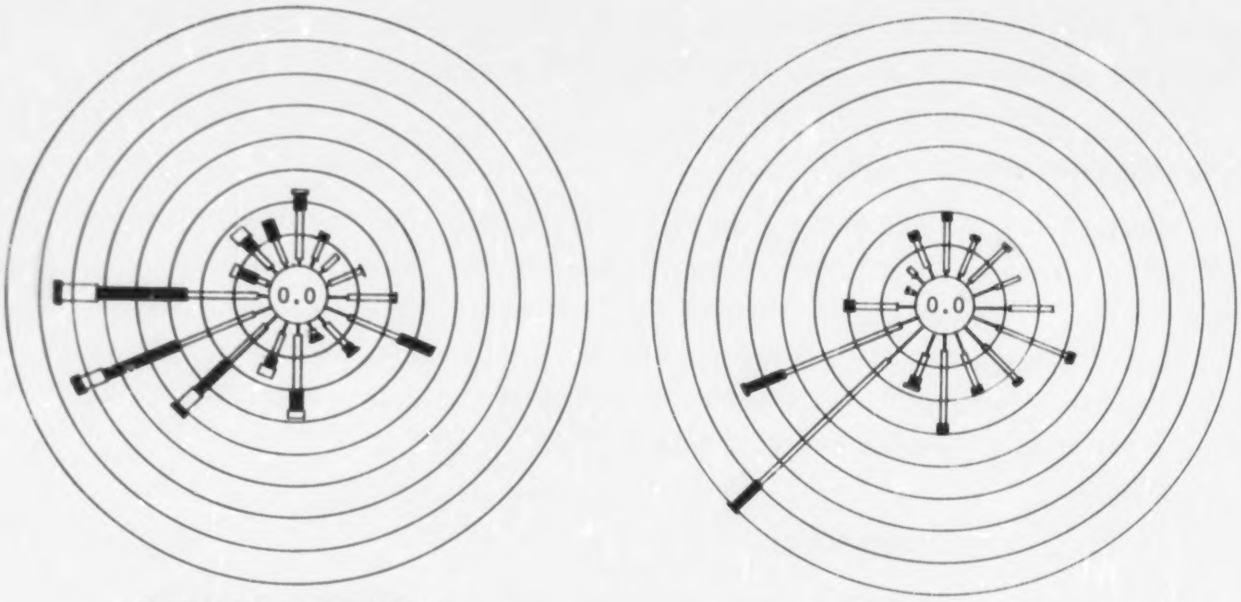
FALL WIND ROSE 1956-60 DATA

WINTER WIND ROSE 1956-60 DATA

Figure B-9. Kanawha County Airport.

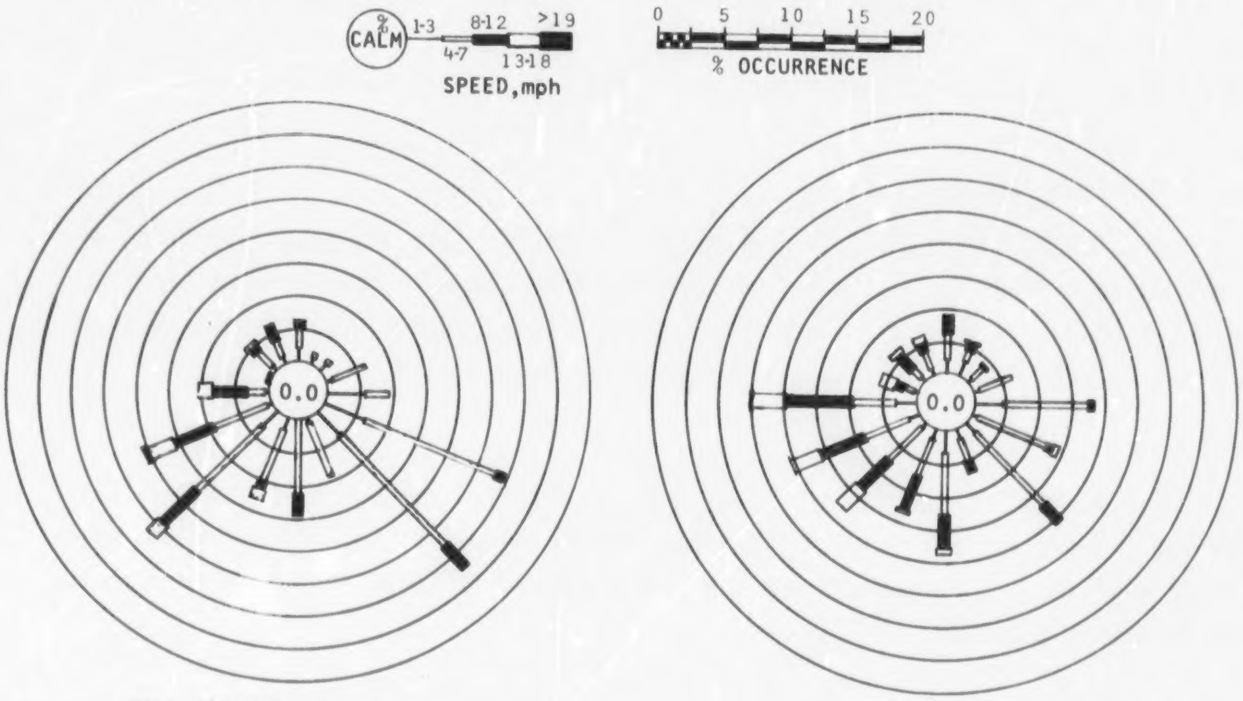
Table B-9. TEMPERATURE AND RELATIVE HUMIDITY AT 400 MOUNTAIN VIEW DRIVE

Hour LST	Spring 1965 1 Mar - 31 May			Summer 1965 1 Jun - 31 Aug.			Fall 1965 1 Sep - 30 Nov			Winter 1964 - 65 1 Dec - 28 Feb			Winter 1965 - 66 1 Dec - 28 Feb		
	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #
0	52.0	75.8	90	66.9	91.7	84	54.0	86.7	91	34.1	73.5	60	33.4	81.6	89
2	49.9	83.5	91	65.0	95.5	84	52.6	89.1	91	33.4	76.8	60	32.4	83.4	89
4	48.3	87.0	91	63.8	97.2	84	51.5	91.8	91	32.6	80.2	60	31.4	86.4	90
6	47.3	89.1	91	63.9	97.1	84	50.7	92.9	91	32.2	81.7	60	30.8	87.1	90
8	49.6	86.5	91	67.3	89.7	80	51.9	92.2	83	31.9	82.7	60	30.6	86.9	89
10	54.8	72.4	90	73.2	73.0	82	57.6	78.4	86	34.9	76.6	60	33.4	84.2	88
12	59.6	60.2	89	77.1	62.4	81	62.9	63.6	85	39.2	66.2	61	37.5	70.5	86
14	62.3	53.8	84	78.6	58.6	82	65.1	57.6	87	41.7	61.9	59	39.5	65.9	87
16	63.7	52.2	85	79.4	56.1	82	65.1	56.4	90	42.6	59.0	59	39.9	64.7	90
18	61.3	56.5	87	77.4	58.7	82	62.3	61.1	91	40.1	62.2	60	38.3	66.3	89
20	58.2	61.2	88	73.8	66.8	84	58.7	70.7	91	37.9	66.4	60	36.4	71.5	89
22	54.9	68.1	88	69.9	80.2	84	55.9	79.7	91	35.8	70.4	61	34.9	77.2	89



SPRING 1225 OBSERVATIONS

SUMMER 805 OBSERVATIONS



FALL 368 OBSERVATIONS

WINTER 763 OBSERVATIONS

Figure B-10. 400 MTN View Drive.

Taft School

Station 61. Beckman and Whitley wind sensors estimated at 630 feet MSL (45 feet above the pavement) were mounted on the Bigley Avenue school which is near the west wall of the Elk River Valley just inside its mouth. Wind roses for the full year ending March 31, 1966 are presented as Figure B-11.

North Charleston Fire Station

Station 17. A hygrothermograph and an actinometer were operated on the roof of the fire station at 500 26th Street and were 20 feet above street level. The area is in a slight depression so that the instruments are estimated at only 30 feet above river pool. Data were recorded from November 14, 1964 through March 31, 1966 and are presented in Table B-10. Pyrheliometer data is summarized in Table 2-1 in the body of the accompanying report.

Union Carbide (South Charleston)

Station 71. Data from an aerovane on the Union Carbide office building in South Charleston were made available by the company. The three-blade rotor estimated to be at 735 feet MSL was 170 feet above the valley floor and near the level of powerhouse stacks about one-quarter mile to the north. Data from April 21, 1965 through March 31, 1966 are used in Figure B-12 wind roses. Calm winds have been distributed among the 1-3 mile per hour groups of the 8 point wind record.

Food Machinery Corporation

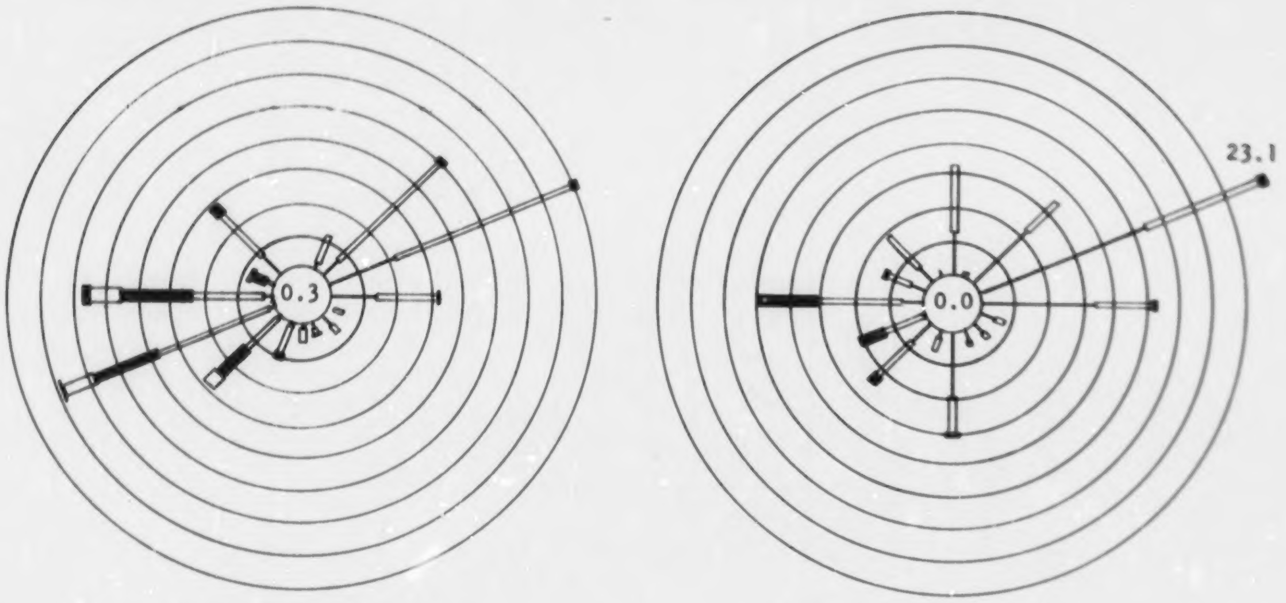
Station 72. About 1/2 mile northwest of station 71, and at an elevation of only 40 feet above the valley floor, another three-blade aerovane was already mounted above the Food Machinery office at 11th and D, South Charleston. A full year's data to March 31, 1966 are portrayed in Figure B-13.

Union Carbide (Institute)

Station 73. Union Carbide also supplied data for the month of January 1966 from a three-blade aerovane in Institute. The sensor was 110 feet above the valley floor near their large stacks but thought to be out of local eddy flow from them. Wind rose is presented as Figure B-14.

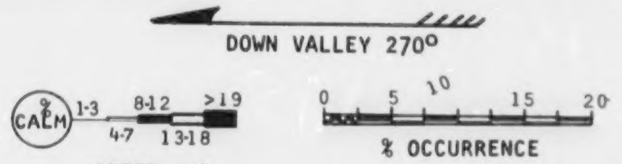
St. Albans

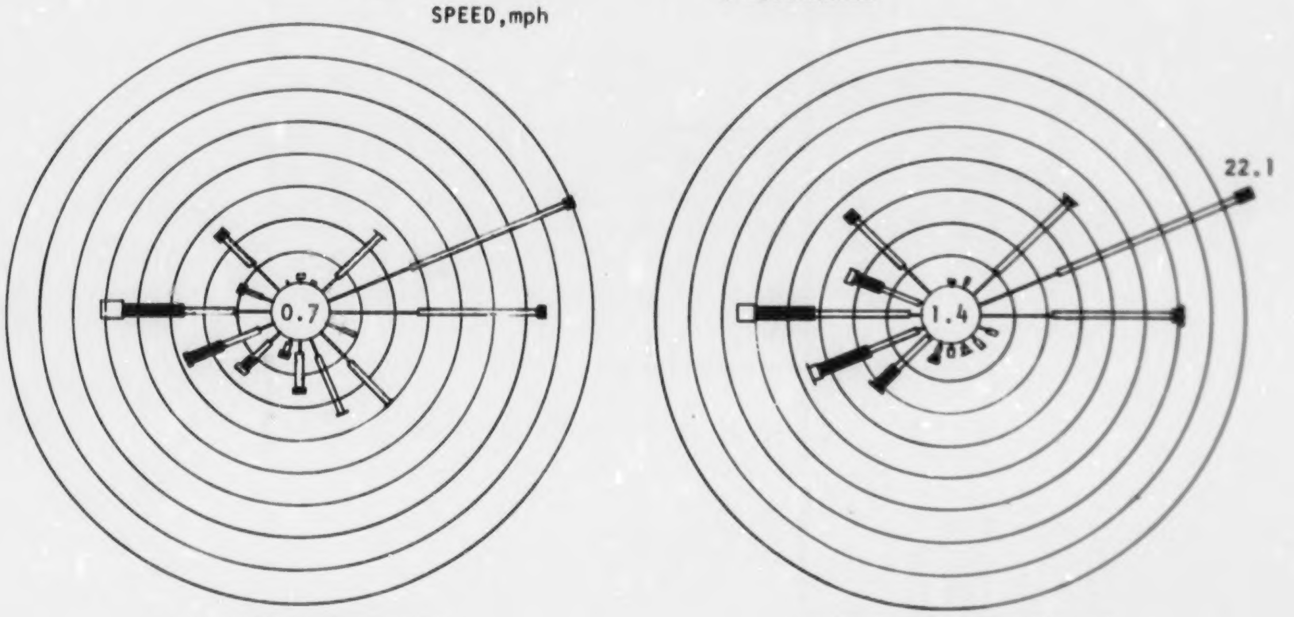
Station 54. The instrument shelter was over bare ground 25 feet above river pool on the grounds of the State Highway garage west of the parking lot. Data between November 19, 1964 and March 31, 1966 are presented in Table B-11.



SPRING 918 OBSERVATIONS

SUMMER 584 OBSERVATIONS


DOWN VALLEY 270°
%
CALM
1-3
4-7
8-12
13-18
>19
SPEED, mph
0
5
10
15
20
% OCCURRENCE



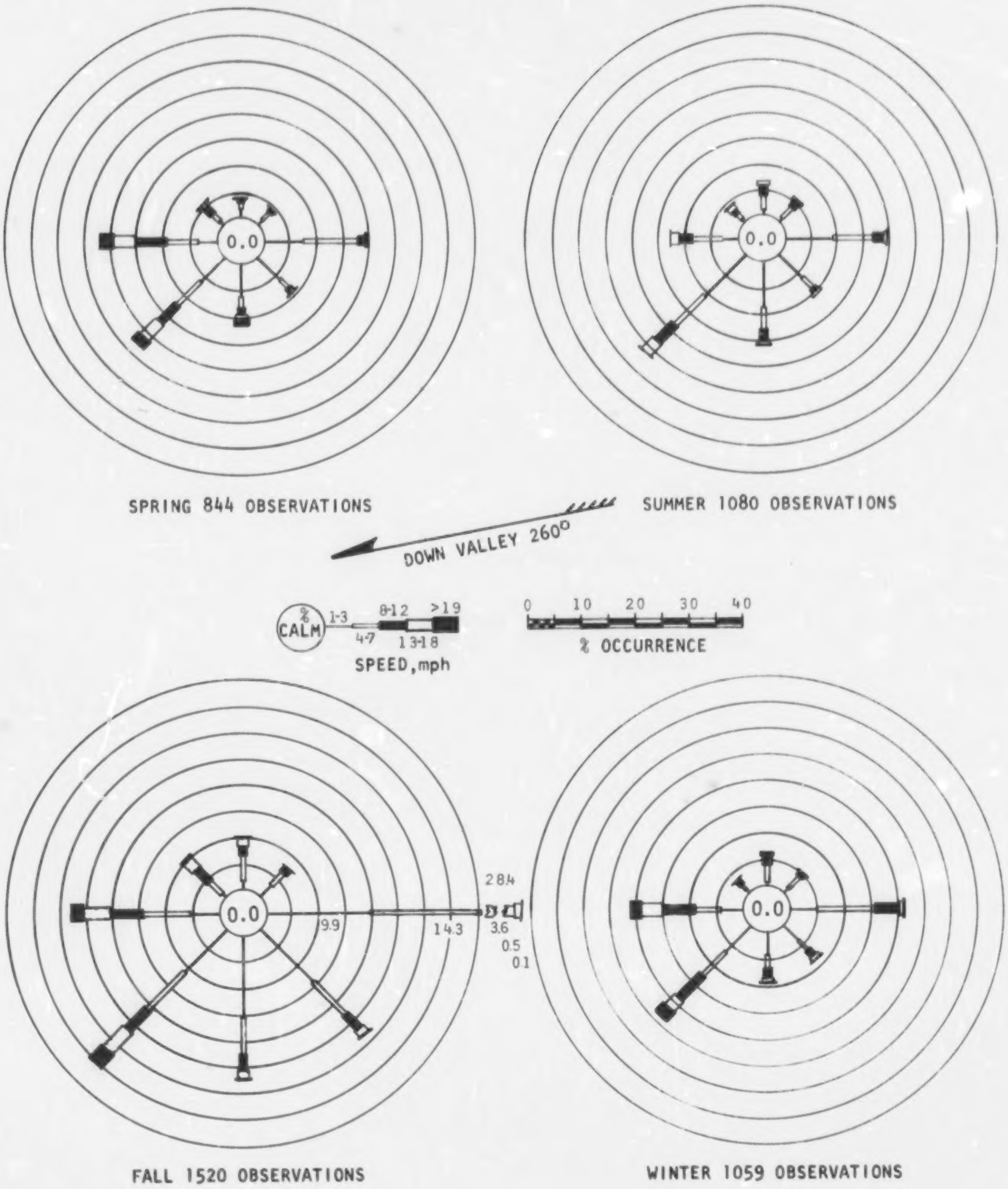
FALL 1162 OBSERVATIONS

WINTER 1768 OBSERVATIONS

Figure B-11. Taft Elementary School.

Table B-10. TEMPERATURE AND RELATIVE HUMIDITY AT NORTH CHARLESTON FIRE STATION

Hour LST	Spring 1965 1 Mar - 31 May			Summer 1965 1 June - 31 Aug.			Fall 1965 1 Sep - 30 Nov			Winter 1964 - 65 1 Dec - 28 Feb			Winter 1965 - 66 - 1 Dec - 28 Feb		
	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #
0	49.3	92.4	83	63.6	99.0	91	49.9	94.8	91	32.8	87.0	90	31.3	91.2	90
2	47.4	94.6	83	62.4	99.5	90	48.7	95.8	91	31.9	88.9	90	30.5	91.4	90
4	46.1	94.7	83	61.5	99.8	91	47.6	96.2	91	31.7	88.4	90	29.7	92.6	90
6	45.6	94.6	83	61.4	99.5	91	47.0	96.3	91	31.4	89.6	90	29.2	92.5	90
8	49.9	81.5	84	66.8	84.7	89	50.4	86.4	82	31.4	87.9	90	29.8	89.7	89
10	57.6	64.2	84	74.4	65.6	85	58.5	64.7	80	35.4	78.8	90	34.1	76.6	86
12	62.8	53.7	84	79.0	56.7	90	64.8	54.0	82	41.0	66.6	89	38.7	65.5	88
14	66.3	48.0	82	81.4	52.7	91	67.1	51.4	89	43.7	62.3	84	41.0	62.7	88
16	66.7	48.9	83	82.0	51.9	92	66.2	52.6	91	44.6	61.3	85	41.6	61.5	90
18	63.8	56.2	84	79.8	58.4	92	59.5	73.2	91	40.4	72.4	89	37.5	75.0	90
20	55.9	76.9	84	72.0	85.4	91	54.0	88.3	91	36.8	81.6	90	34.7	85.0	90
22	52.0	87.1	83	66.4	96.5	91	51.4	92.3	91	34.7	84.4	90	32.9	89.6	90



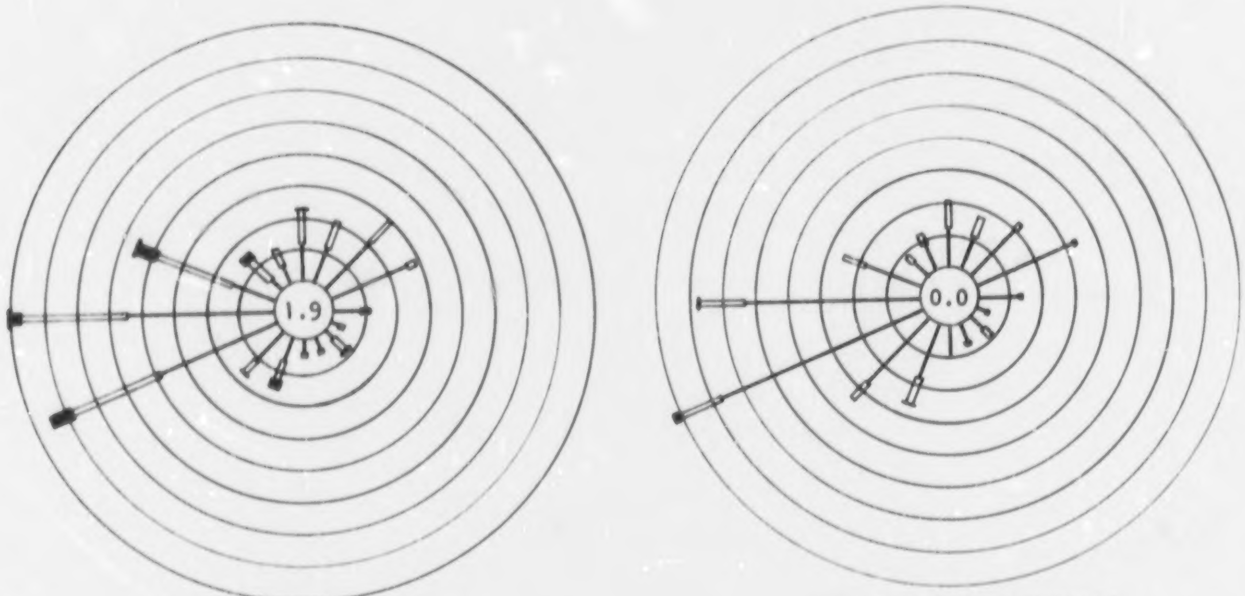
SPRING 844 OBSERVATIONS

SUMMER 1080 OBSERVATIONS

FALL 1520 OBSERVATIONS

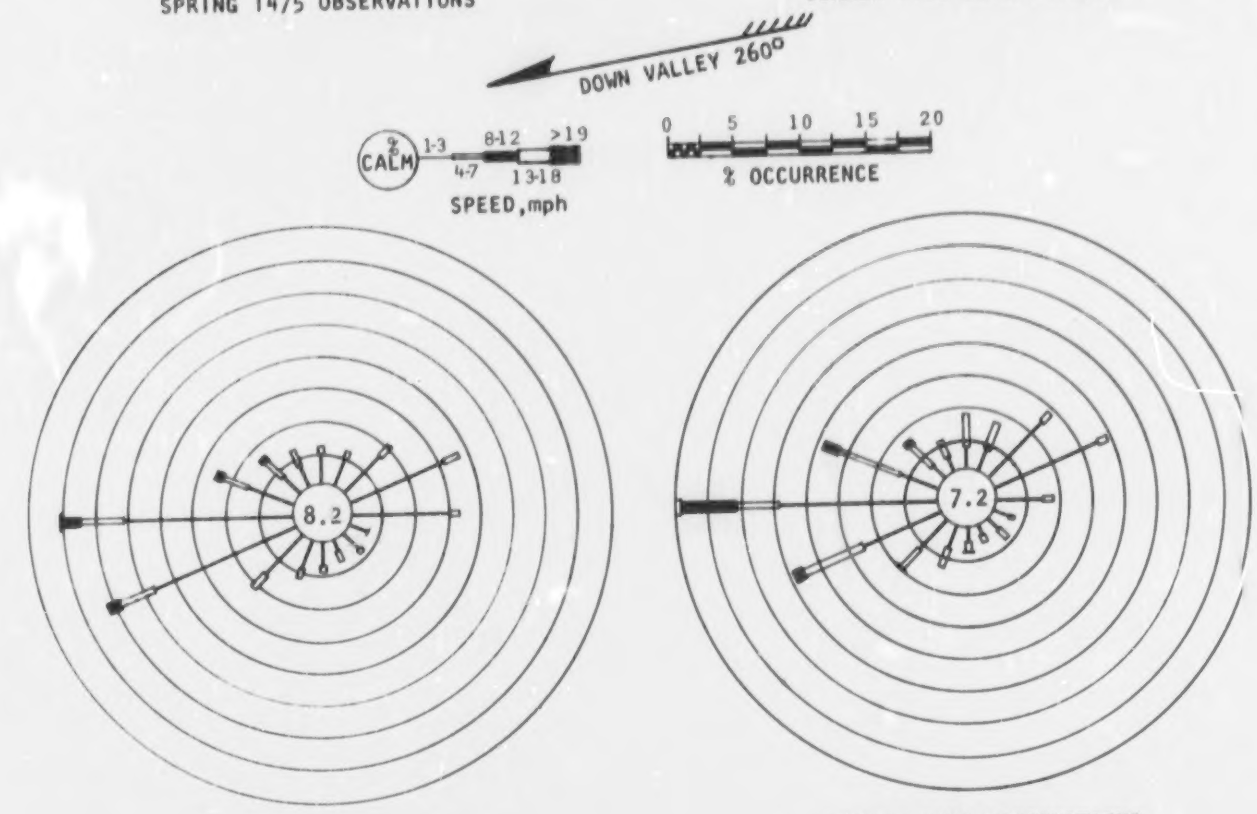
WINTER 1059 OBSERVATIONS

Figure B-12. Union Carbide, South Charleston.



SPRING 1475 OBSERVATIONS

SUMMER 1102 OBSERVATIONS



FALL 2158 OBSERVATIONS

WINTER 2090 OBSERVATIONS

Figure B-13. Ford Machinery Corporation.

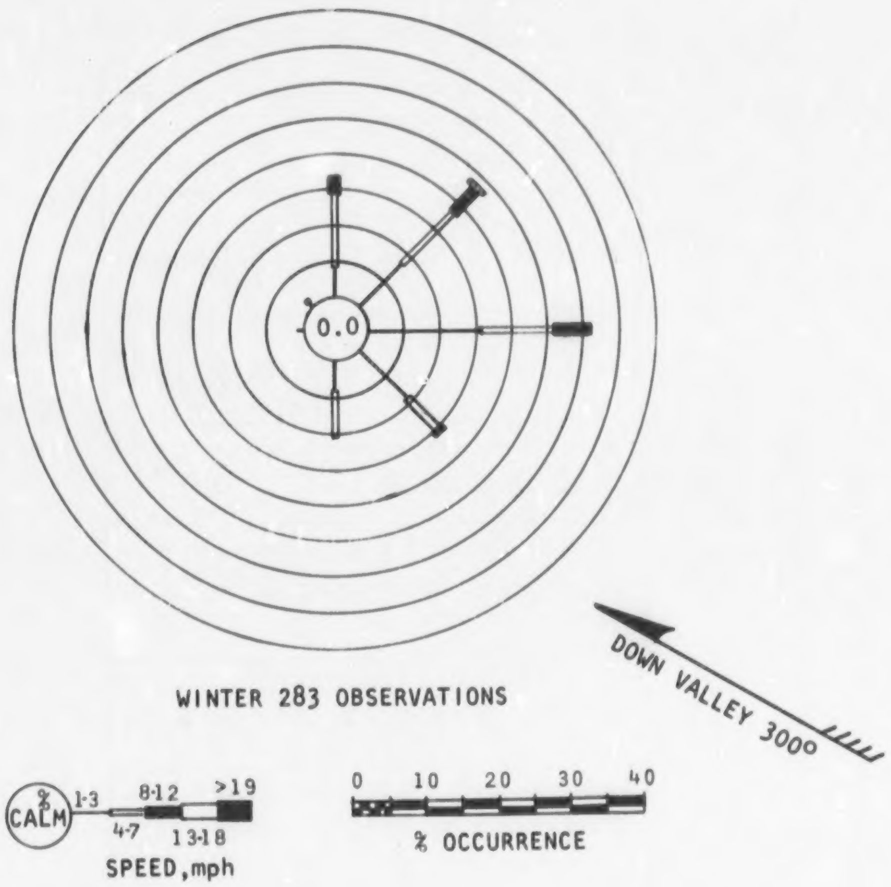


Figure B-14. Union Carbide, Institute.

West Sattes School

Station 62. Over the school building which is in Nitro opposite the mouth of the Cole River, a Beckman and Whitley wind sensor was installed 35 feet above ground level and 100 feet north of the Kanawha River bank. Wind roses in Figure B-15 are from a complete year's data ending March 31, 1966.

General Chemical (Nitro)

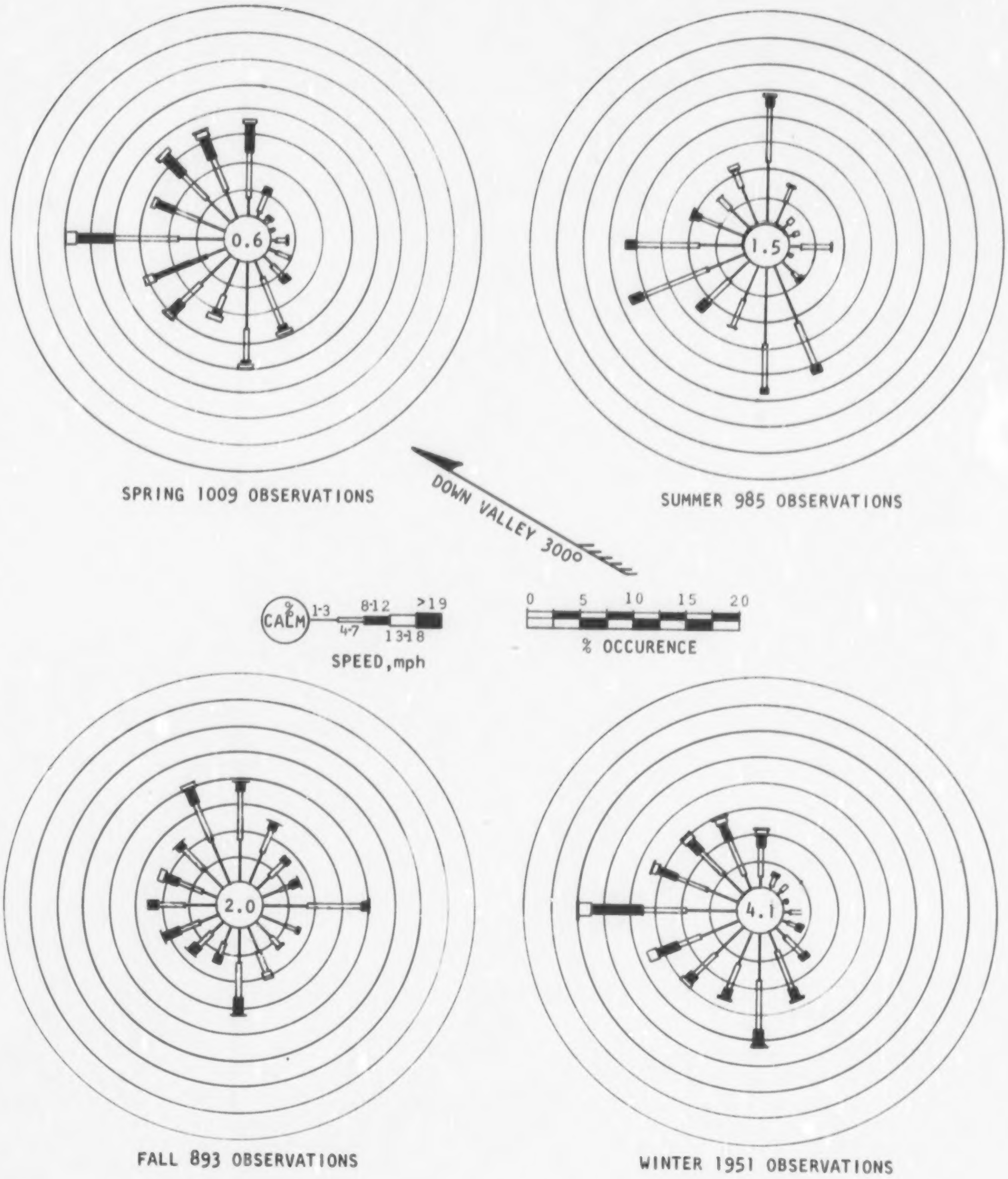
The General Chemical Division of Allied Chemical Corporation operates a wind system at their Viscose Road installation in Nitro. This system consists of a Robinson anemometer mounted on a shaft 30 feet above the valley floor and a triple register recorder. Wind data for the year ending March 31, 1966 were used for Figure B-16 wind roses.

Nitro

Station 55. An instrument shelter was placed on the grounds of the Nitro Sewage Treatment Plant at a point about 500 feet east of the river. The plant is north of the main part of the town on low land so that high humidity with frequent

Table B-11. TEMPERATURE AND RELATIVE HUMIDITY AT ST. ALBANS

Hour LST	Spring 1965 1 Mar - 31 May			Summer 1965 1 June - 31 Aug.			Fall 1965 1 Sep - 30 Nov			Winter 1964 - 65 1 Dec - 28 Feb			Winter 1965 - 66 1 Dec - 28 Feb		
	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #
0	47.9	90.1	80	64.6	97.6	90	49.4	94.6	87	33.9	85.9	90	30.9	89.8	90
2	46.3	93.5	80	63.1	98.6	90	48.1	96.1	87	33.0	88.6	90	30.0	90.9	90
4	45.5	93.9	79	61.9	99.5	89	47.2	96.7	87	32.7	88.0	90	29.1	92.4	90
6	45.1	94.7	80	62.3	98.9	89	46.8	97.0	84	32.2	88.6	90	28.4	92.6	90
8	49.0	85.6	79	69.0	83.2	86	50.8	91.4	78	32.5	88.3	87	29.0	90.7	87
10	55.7	70.9	78	75.7	67.6	89	59.7	70.8	80	36.5	80.2	85	33.7	81.7	85
12	60.3	58.3	78	80.1	59.6	90	64.8	57.9	85	41.6	67.7	82	38.8	70.3	88
14	62.8	53.6	77	81.9	56.0	90	66.6	54.2	87	44.1	65.3	78	41.2	65.1	90
16	62.4	54.7	78	81.6	55.7	90	65.6	56.1	88	44.5	62.8	82	41.1	63.3	90
18	59.9	59.8	78	78.5	62.1	90	59.1	71.4	87	40.6	72.3	82	37.4	71.4	90
20	54.3	72.5	78	72.0	81.5	90	53.9	84.3	87	37.3	79.0	87	34.1	82.2	90
22	50.4	84.3	78	67.3	93.1	90	51.0	91.0	87	35.5	82.7	90	32.6	87.6	90



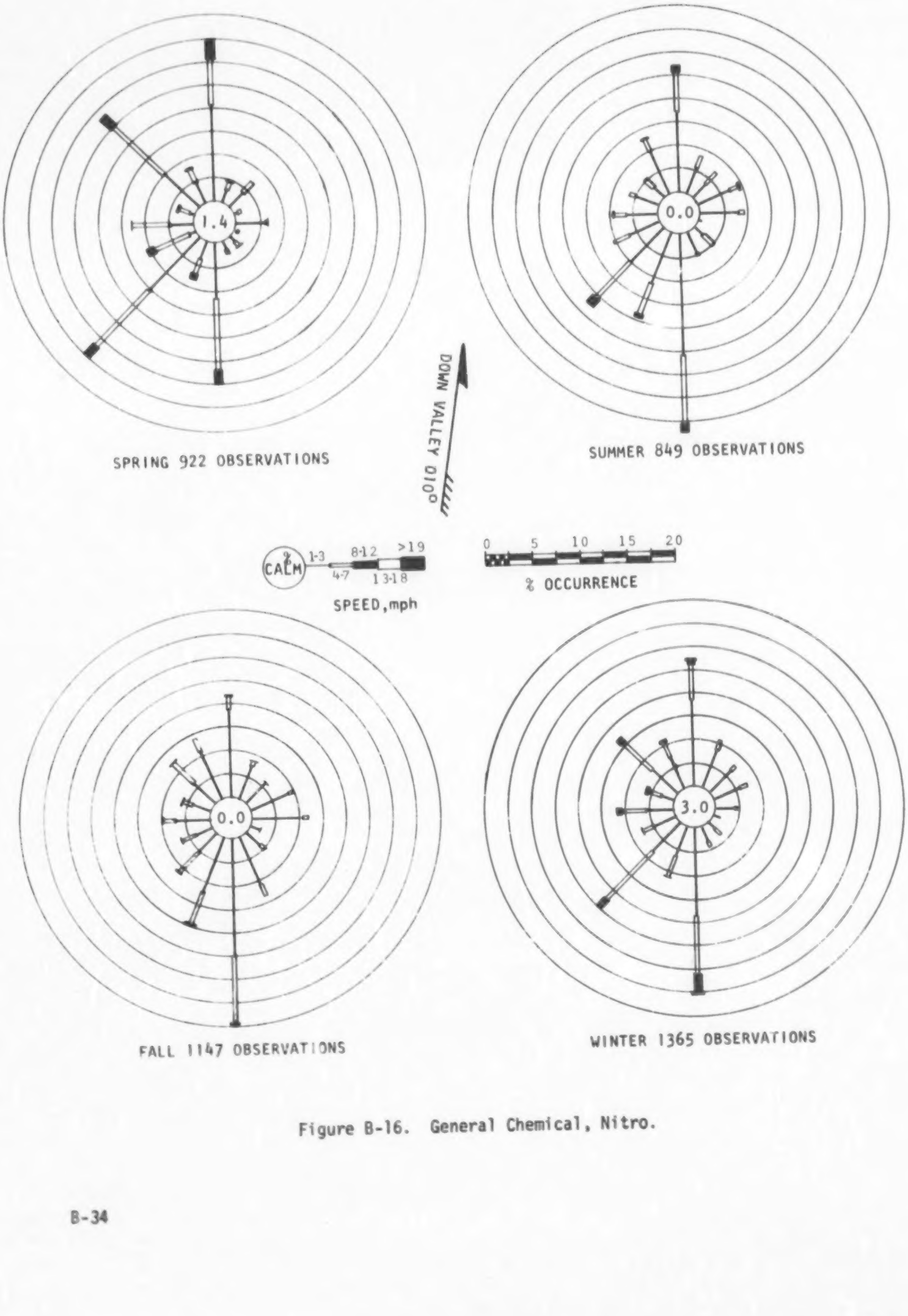
SPRING 1009 OBSERVATIONS

SUMMER 985 OBSERVATIONS

FALL 893 OBSERVATIONS

WINTER 1951 OBSERVATIONS

Figure B-15. West Sattes Elementary School



SPRING 922 OBSERVATIONS

SUMMER 849 OBSERVATIONS

FALL 1147 OBSERVATIONS

WINTER 1365 OBSERVATIONS

Figure B-16. General Chemical, Nitro.

morning fog is normal. The shelter was over grass and near large treatment ponds, but free from shade. Hygrothermograph recorded from November 1964 through March 31, 1966; data being presented as Table B-12.

INTENSIVE STUDY

The work carried out during an intensive study of winds and temperatures required additional facilities and personnel. Tethersonde ascent, pibal tracking, and tetroon launching each require an open area. These activities are impossible during appreciable precipitation since moisture reduces visibility, makes the rate of rise uncertain, and tends to short out the radio transmitter. Winds of 25 miles per hour damage or carry away the Aerokite, so this instrument was kept deflated or in a shelter when such winds threatened. Personnel and equipment shelters were provided in the form of a 10-foot camping trailer and a truck with a 14-foot-long box, both rented when needed.

Commercial 60-cycle power was necessary for satisfactory operation of tethersonde components. Aircraft tracking of the tetroon limited the operation to periods of daylight when ceiling and visibility allowed reasonably safe operation at low levels, both at the airport and within the valley. Morning aircraft tracking was not feasible, because of low visibility within the valley, and tracking by automobile was resorted to in order to study early morning air flow. The West Virginia Air National Guard plane, shown in Figure B-17, was most useful in tracking tetroons later in the day. Aerial photographs in this report were obtained during these flights, which were made under a Federal Aviation Agency waiver of minimum flight altitude over the city.

The plan called for around-the-clock data and consisted of tracking a pibal to 5,000 feet each odd hour and a tethersonde to 1,000 feet each even hour.. Tetroons were to be released shortly after sunrise and 1 hour before sunset.

The initial operation of January 25-30, 1965, was from the area behind Charleston City Hall, shown in Figure B-1. This location had been cleared and was made available by the Urban Renewal Authority. Power from the small building behind the study trailer was kindly provided by the operator of the parking lot, and the tethersonde was flown from that location.

Eight men from Cincinnati were used in this program, with one part-time man from the project office. This provided two men for each 8-hour shift, a supervisor who also acted as aerial observer, a man who was experienced in inflating tetroons, and a trainee. In addition, other men from the project office gained

Table B-12. TEMPERATURE AND RELATIVE HUMIDITY AT NITRO

Hour LST	Spring 1965 1 Mar - 31 May			Summer 1965 1 June - 31 Aug.			Fall 1965 1 Sep - 30 Nov			Winter 1964 - 65 1 Dec - 28 Feb			Winter 1965 - 66 1 Dec - 28 Feb		
	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #	Temp. °F	R.H. %	Obs. #
0	47.9	94.1	91	63.1	98.5	92	51.0	95.8	88	32.0	88.7	88	31.2	91.9	90
2	46.4	95.5	91	61.8	99.1	92	50.1	97.6	87	31.4	91.8	87	30.6	92.5	90
4	45.3	94.7	91	61.0	99.3	92	49.3	98.2	87	30.9	91.7	87	29.6	93.5	90
6	45.1	95.2	91	61.1	99.3	92	48.9	98.1	87	31.0	92.0	87	29.2	93.8	90
8	49.5	91.7	92	67.7	94.6	89	51.7	97.0	81	31.1	91.0	85	30.1	92.8	88
10	56.5	75.1	92	74.5	79.3	88	60.6	80.8	79	35.2	84.1	85	34.9	86.9	86
12	61.1	62.6	92	78.4	67.8	91	65.8	65.1	82	40.0	72.7	84	39.4	72.9	87
14	63.4	56.7	92	80.5	61.9	92	67.4	59.3	86	42.7	67.4	82	41.7	65.8	87
16	63.0	55.9	92	80.2	60.9	92	66.6	59.3	88	43.3	66.0	83	41.7	64.2	89
18	60.5	60.2	92	77.7	65.3	92	60.8	71.8	88	39.0	74.5	85	37.5	72.4	89
20	53.9	77.0	92	70.6	85.6	92	54.5	90.3	88	35.0	83.7	87	34.1	84.7	90
22	49.8	91.9	92	65.4	97.4	92	52.1	93.5	88	33.3	87.0	88	32.7	89.5	90

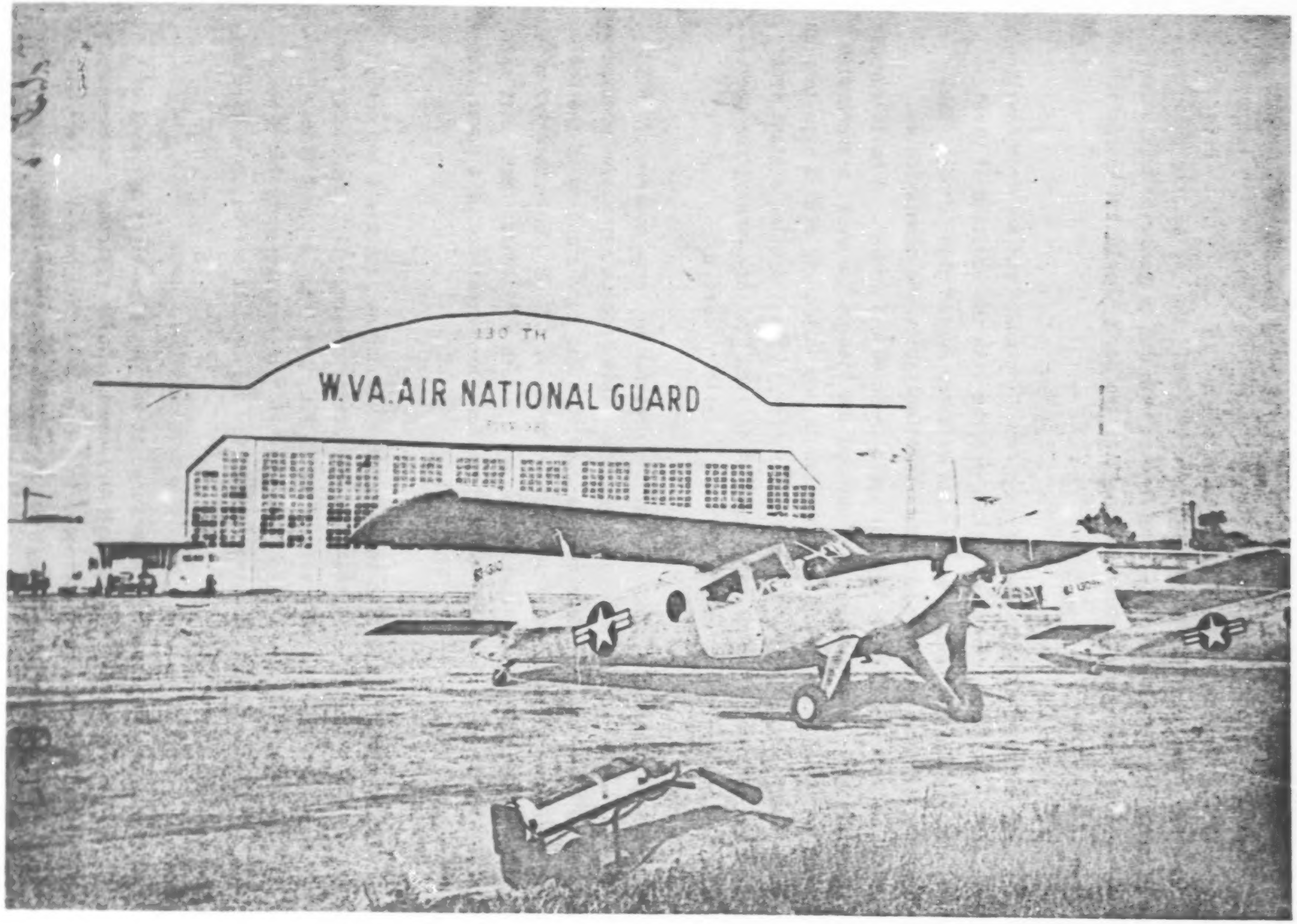

130 TH
W.VA. AIR NATIONAL GUARD

Figure B-17. U-10 Helicourier W. Va. ANG 130th Air Commando Group.

some experience, though not formally scheduled to be on duty. During the operation, tethersonde ascents were beneath the glide path of planes on final approach to Kanawha Valley Airport and were a source of concern to some pilots. With southeast winds, the Aerokite was carried over City Hall and the police radio transmitter antenna there caused serious interference with the tethersonde transmitter. For these reasons, the spring study was moved to the North Charleston Recreation Area shown in Figure B-2.

In May, eight men again were assigned from Cincinnati and one from Sterling, Virginia. This was another round-the-clock program with the addition of pibal observations from the Mobile Laboratory site at Nitro Junior High School. The North Charleston Recreation Area was found to be suitable, and permission was obtained to use this location in May and again in October-November. A multi-purpose recreation building and a swimming pool bounded the site on the west, a creek with small trees on the east, a playfield on the south, and a highway with a high-tension power line on the north. Since the Recreation Area is about 4 miles distant from (and about 400 feet below) the airport and not in line with any runway, the operations at this site did not interfere with the aviation interests.

For the July series of observation, the presence of large numbers of childeren in the Recreation Area site posed a problem. This problem was solved when permission was obtained to use undeveloped land adjacent to and belonging to the Kelly Works of Tru-Temper Corporation, shown in Figures B-2 and B-18. Less than 1/2 mile from the Recreation Area site, separated by a creek and a railroad track, this site had all the advantages of the other site, save for the convenience of a power supply and sanitary facilities.

The staff members felt that the data obtained during late night and early afternoon did not justify around-the-clock operation; consequently, the summer and fall operations were cut to two shifts, 4 to 12 a.m. and 3 to 11 p.m. These shifts covered the periods of maximum change. In July with the reduction to two 8-hour shifts and additional personnel being trained for the project office, only five men were required from Cincinnati.

Wind direction and speed were measured at various elevations by means of pibals in the Kanawha Valley. These data are compared with radiosonde measurements at a 2,000-foot elevation over Huntington in Tables B-13 through B-17. For ease of comparison, data are grouped into daytime, nighttime, and transitional hours. Direction from which the wind was blowing is given in degrees and wind speed is given in miles per hour.

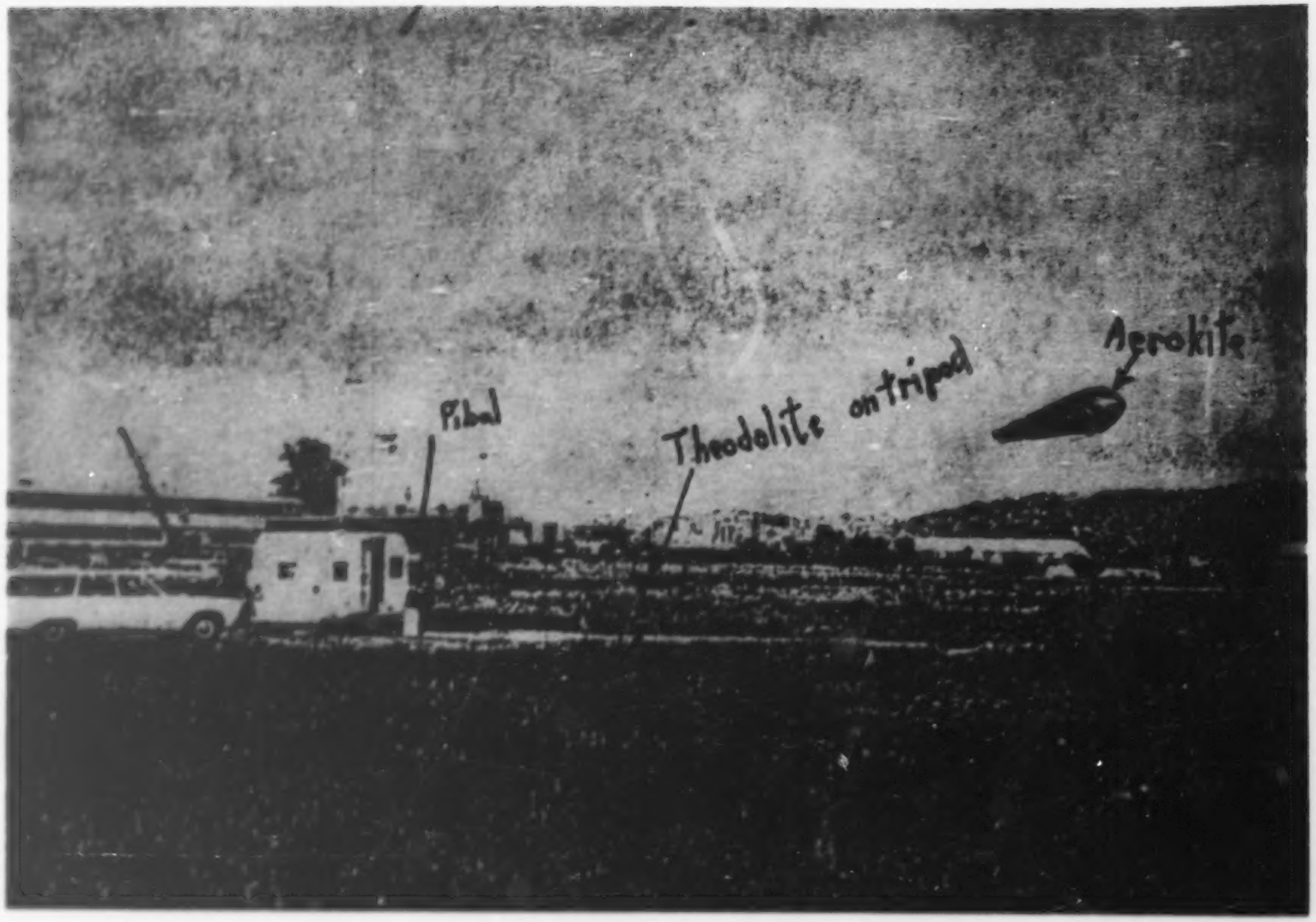

Pibal
Theodolite on tripod
Aerokite

Figure 8-18. Tru-Temper Intensive Study Site used in summer 1965.

Table B-13. WINDS MEASURED AT CHARLESTON COMPARED WITH WINDS AT HUNTINGTON - WINTER 1965

		Charleston													Huntington	
Elevation, ft		Surface		260		490		710		1370		2430		2000		
Date	Time	Direction, degrees	Speed, mph	Direction, degrees	Speed, mph	Direction, degrees	Speed, mph	Direction, degrees	Speed, mph	Direction, degrees	Speed, mph	Direction, degrees	Speed, mph	Time	Direction, degrees	Speed, mph
1-25	1705	200	M	191	6.4	177	4.4	201	7.0	212	11.0	207	21.6	1900	190	25
1-26	1300	273	M	268	22.4	247	19.6	238	22.4	253	43.4	256	42.0			
	1500	258	M	249	19.4	241	21.6	238	19.0	261	20.4	254	33.2	1900	270	19
	1700	286	M	285	31.0	287	26.0	290	37.0	290	34.0	271	60.0			
1-27	1300	291	15.4	294	12.0	293	20.4	293	28.4	290	30.2	276	16.4			
	1500	299	M	293	21.8	289	19.8	289	20.4	283	17.4	262	14.8	1900	280	17
	1700	289	M	291	14.2	292	15.0	292	18.0	290	23.0	286	24.5			
1-28	1300	290	M	282	8.0	239	9.5	263	14.2	272	10.0	253	17.6			
	1500	292	M	292	12.2	295	17.0	274	25.3	264	26.2	261	26.4	1900	310	15
1-29	1300	312	M	304	12.0	295	8.7	287	10.0	272	18.1	250	11.2			
	1500	302	M	300	7.3	302	6.9	287	5.6	255	5.8	250	16.0	1900	M	M
	1655	325	M	329	10.8	328	10.9	321	9.0	291	9.2	324	9.0			
1-25	2100	215	M	180	8.3	173	13.0	184	17.2	206	21.4	196	23.0			
	2325	190	M	165	8.4	193	8.8	201	15.8	226	33.2	236	51.2			
1-26	0300	128	M	155	7.4	163	9.0	169	15.0	201	8.8	195	10.6	0700	200	27
	0500	M	M	135	4.6	160	8.6	192	11.2	M	M	M	M			
	2055	302	M	305	14.0	295	16.0	289	16.0	304	19.6	M	M			
	2250	269	M	261	30.0	262	23.0	268	19.3	292	22.2	M	M			
1-27	0102	275	M	275	15.2	270	13.0	273	25.4	272	31.8	274	18.4			
	0300	290	M	292	11.2	277	15.2	272	16.5	273	14.9	278	27.0	0700	270	23
	0500	292	M	278	7.0	292	9.2	273	11.4	285	19.0	258	9.0			
	2058	210	M	231	6.0	244	15.5	255	19.0	262	21.0	274	21.0			
	2248	248	M	241	9.5	239	17.5	242	19.0	247	34.5	265	28.5			
1-28	0100	168	M	190	6.0	210	2.0	223	14.4	232	35.0	M	M	0700	M	M
	0300	190	M	205	5.0	224	10.0	225	17.5	232	38.0	249	36.0			
	0500	193	M	226	14.0	237	21.7	231	22.8	242	21.9	258	39.0			
1-29	0315	267	M	264	2.0	275	3.3	284	4.2	328	4.0	298	5.0	0700	280	15
	0450	271	M	274	5.5	275	16.0	275	20.0	299	11.0	272	20.0			
	2115	016	M	027	7.5	044	7.0	053	6.4	074	3.6	214	16.0			
	2302	027	M	040	3.8	089	1.9	078	2.9	091	10.0	267	13.0			
1-30	0100	015	M	046	3.4	050	5.2	058	4.4	119	3.6	290	9.8	0700	040	10

M = Missing data.

Table B-14. WINDS MEASURED AT NORTH CHARLESTON COMPARED WITH WINDS AT HUNTINGTON - SPRING 1965

		North Charleston												Huntington		
Elevation,ft		Surface		260		490		710		1370		2430		2000		
Date	Time	Direction, degrees	Speed, mph	Direction, degrees	Speed, mph	Direction, degrees	Speed, mph	Direction, degrees	Speed, mph	Direction, degrees	Speed, mph	Direction, degrees	Speed, mph	Time	Direction, degrees	Speed, mph
5-3	1500	M	M	M	M	249	2.4	277	5.2	243	6.2	241	9.3	1900	240	13
5-3	1700	M	M	M	M	M	M	286	10.0	278	15.1	254	20.6			
5-3	1900	M	M	246	17.1	252	15.1	252	11.4	259	14.9	254	19.9			
5-4	1300	288	9.6	291	8.0	290	8.1	288	10.3	281	20.8	269	13.5			
5-4	1500	240	10.6	250	8.8	259	9.6	251	9.5	247	9.1	246	13.9	1900	270	11
5-4	1700	278	17.2	275	15.3	270	10.5	253	7.5	238	10.6	268	3.8			
5-5	1300	268	9.2	271	8.0	276	8.2	273	10.1	277	7.8	275	6.4			
5-5	1500	278	11.7	270	13.8	261	13.6	259	11.4	283	2.2	281	8.4	1900	230	2
5-5	1700	150	2.7	173	5.0	182	10.0	192	9.2	223	13.8	280	13.0			
5-6	1300	256	2.4	254	3.7	255	3.4	255	5.0	266	7.0	242	9.3			
5-6	1500	285	2.4	298	4.0	305	4.7	293	6.0	316	7.2	M	M	1900	250	6
5-6	1700	252	6.0	264	5.7	276	6.2	279	6.0	294	5.0	300	3.0			
5-7	1301	274	7.1	265	6.2	260	5.3	270	6.0	293	5.2	330	5.7			
5-7	1500	068	7.2	050	6.2	027	8.6	024	9.7	024	12.8	060	3.0	1900	040	3
5-7	1700	010	6.9	008	7.5	008	8.0	006	8.2	018	7.2	360	3.6			
5-3	2100	046	2.0	091	2.1	228	3.5	265	5.2	269	16.2	252	17.4			
	2300	M	M	M	M	M	M	M	M	M	M	304	18.7			
5-4	0100	M	M	M	M	152	M	180	3.2	M	M	291	23.2	0700	270	17
	0257	M	M	111	5.2	158	5.5	210	7.8	273	11.7	292	26.2			
	0510	069	3.4	098	3.6	137	4.6	226	10.0	268	12.2	296	20.0			
	2100	118	M	M	M	M	M	M	M	305	15.2	305	13.0			
	2320	084	4.2	103	5.5	133	4.9	241	1.8	316	19.1	281	19.2			
5-5	0105	099	M	123	5.2	164	5.1	209	6.9	272	14.0	281	14.1	0700	250	18
	0300	105	M	117	4.2	188	5.0	221	8.8	263	14.2	279	23.5			
	0458	095	4.1	113	4.2	179	4.8	222	6.2	260	19.8	278	26.2			
	2100	100	2.8	138	2.3	172	4.0	213	8.2	250	13.0	247	9.4			
	2300	Fog	Fog	M	M	M	M	M	M	M	M	M	M			
5-6	0100	Fog	Fog	M	M	M	M	M	M	M	M	M	M	0700	280	11
	0300	Fog	Fog	M	M	M	M	M	M	M	M	M	M			
	0500	Fog	Fog	M	M	M	M	M	M	M	M	M	M			
	2100	089	4.8	100	4.6	101	0.7	281	2.1	295	8.2	288	10.4			
	2315	106	3.4	115	8.2	136	5.2	268	3.8	317	14.4	315	14.2			
5-7	0112	089	2.2	109	2.6	137	5.4	162	5.0	152	1.2	296	8.0	0700	270	6
	0300	094	1.9	106	2.1	138	3.6	194	4.8	251	6.8	317	7.8			
	0500	094	2.0	119	2.7	135	3.4	131	3.4	269	3.6	328	9.2			
	2100	084	5.8	116	6.0	127	9.2	122	12.2	135	13.9	123	9.9			
	2321	113	2.6	126	5.0	168	6.8	182	12.6	178	19.8	183	13.6			
5-8	0103	090	3.2	100	5.0	117	4.8	140	5.4	197	12.2	227	17.6	0700	190	3
	0301	104	5.1	109	6.6	114	8.1	134	7.9	204	9.6	267	9.2			
	0505	095	5.1	105	5.7	111	6.9	141	7.3	225	4.2	297	16.1			

M = Missing data.

Table B-15. WINDS MEASURED AT NITRO COMPARED WITH WINDS AT HUNTINGTON - SPRING 1965

		NITRO												Huntington		
Elevation,ft		Surface		260		490		710		1370		2430		2000		
Date	Time	Direction, degrees	Speed, mph	Direction, degrees	Speed, mph	Direction, degrees	Speed, mph	Direction, degrees	Speed, mph	Direction, degrees	Speed, mph	Direction, degrees	Speed, mph	Time	Direction, degrees	Speed, mph
5-4	1533	285	7.8	276	9.2	252	8.5	249	10.0	250	8.2	248	10.3	1900	270	11
5-5	1600	105	M	174	4.8	189	6.8	199	7.9	162	3.8	335	12.6	1900	230	2
5-6	1600	200	3.0	213	3.0	209	3.3	221	3.2	278	2.8	227	14.1	1900	250	6
5-7	1639	360	M	357	6.4	347	7.2	346	5.9	007	3.9	007	17.8	1900	040	3
5-4	0701	198	5.3	190	5.2	202	8.9	217	12.0	285	13.5	297	19.0	0700	270	17
5-5	0700	199	2.2	193	6.7	204	10.8	220	17.8	245	22.2	268	19.3	0700	250	18
5-6	0722	M	M	198	3.4	179	4.5	213	7.2	310	17.9	316[a]	15.0[a]	0700	280	11
5-7	0700	M	M	M	M	M	M	M	M	M	M	M	M	0700	270	6

[a] At 1,795 ft.

M = Missing data

Table B-16. WINDS MEASURED AT NORTH CHARLESTON COMPARED WITH WINDS AT HUNTINGTON - SUMMER 1965

		North Charleston												Huntington		
Elevation, ft		Surface		260		490		710		1370		2430			2000	
Date	Time	Direction, degrees	Speed, mph	Direction, degrees	Speed, mph	Direction, degrees	Speed, mph	Direction, degrees	Speed, mph	Direction, degrees	Speed, mph	Direction, degrees	Speed, mph	Time	Direction, degrees	Speed, mph
7-26	1705	315	8.0	314	7.0	319	5.7	330	5.3	324	5.0	266	4.8	1900	020	8
7-26	1912	318	5.7	299	7.5	309	8.5	295	6.7	296	3.0	343	4.6			
7-27	1700	019	11.3	020	11.3	019	10.8	013	8.3	338	6.3	299	4.0	1900	M	M
7-27	1902	004	3.0	010	3.2	034	2.2	031	3.3	025	6.4	M	M			
7-28	1700	011	6.4	018	6.7	012	8.1	006	10.9	011	10.7	351	7.2	1900	030	8
7-28	1900	023	5.0	016	7.7	011	10.8	013	12.6	014	12.8	025	12.0			
7-29	1700	319	11.8	325	11.1	343	10.2	356	9.3	319	6.0	331	8.1	1900	340	12
7-29	1900	321	6.5	332	8.3	342	11.5	343	13.8	340	12.2	340	13.5			
7-30	1700	328	2.5	340	2.2	356	1.9	357	1.4	353	2.6	004	3.0	1900	030	4
7-30	1907	346	5.8	342	7.2	340	9.5	343	10.3	350	10.2	358	8.6			
7-27	0312	108	3.4	121	3.8	156	8.2	243	0.5	064	1.8	004	4.2	0700	300	9
7-27	0510	092	3.2	113	3.5	193	3.8	Fog	M	M	M	M	M			
7-28	0300	068	5.6	095	5.0	123	5.5	182	2.8	261	4.8	304	12.4	0700	010	10
7-28	0500	098	5.4	111	4.6	128	3.8	Fog	M	M	M	M	M			
7-29	0305	024	1.2	267	0.9	301	3.1	335	6.7	325	10.0	258	4.2	0700	030	16
7-29	0500	343	4.8	331	5.0	313	4.1	317	3.3	005	5.7	Fog	Fog			
7-30	0300	184	0.8	Calm	Calm	Calm	Calm	278	2.1	047	9.5	062	11.1	0700	M	M
7-30	0500	047	0.8	117	1.7	158	1.6	298	0.9	074	8.6	077	6.9			
7-31	0300	091	3.9	115	4.6	132	4.7	092	3.8	079	13.7	103	10.7	0700	M	M
7-31	0500	068	2.3	111	3.3	136	2.8	141	3.1	107[a]	11.2	Low clouds				
7-26	2120	350	2.9	350	1.3	170	0.6	297	2.3	334	10.6	341	5.7			
7-26	2314	Calm	Calm	Calm	Calm	Calm	Calm	240	M	340	8.0	347	7.2			
7-27	0706	057	4.8	088	4.6	135	4.8	161	4.8	Fog	Fog	M	M			
7-27	0901	046	2.1	038	1.8	152	0.5	219	1.8	322	8.4	318	8.2			
7-27	2105	088	2.6	093	2.5	088	2.2	068	1.8	355	3.5	M	M			
7-27	2300	M	M	113	2.8	108	3.0	105	3.6	295	5.6	294	11.2			
7-28	0700	050	4.7	069	3.4	105	2.8	Fog	Fog	M	M	M	M			
7-28	0900	008	3.0	336	2.9	316	4.4	325	6.5	352	7.2	055	7.4			
7-28	2103	M	M	M	M	M	M	M	M	035	19.4	048	10.1			
7-28	2300	071	2.1	110	1.9	129	1.7	061	2.5	035	13.0	034	15.0			
7-29	0708	006	2.9	017	3.7	345	6.8	355	10.4	071	6.2	083	8.4			
7-29	0900	009	6.0	021	5.2	060	6.1	077	7.2	037	9.8	029	13.2			
7-29	2100	344	4.8	346	6.0	348	10.6	355	15.2	355	18.4	001	16.9			
7-29	2300	M	M	322	4.0	M	M	348	13.0	359	28.3	019	19.2			
7-30	0700	325	2.3	292	1.9	269	2.7	284	2.8	037	2.8	050	4.6			
7-30	0900	105	4.7	108	4.3	117	2.2	116	2.2	018	5.8	020	6.8			
7-30	2100	046	2.8	065	2.3	025	2.5	340	3.8	013	13.2	024	11.7			
7-30	2300	342	2.1	265	1.2	235	1.6	016	3.1	009	16.8	046	14.8			
7-31	0600	070	3.0	097	2.8	131	4.8	133	6.4	Low clouds		M	M			
7-31	0900	084	2.6	091	2.6	098	2.0	158	3.5	175	14.4	204	10.7			

[a] At 450 ft.

M = Missing data.

Table B-17. WINDS MEASURED AT NORTH CHARLESTON COMPARED WITH WINDS AT HUNTINGTON - FALL 1965

		North Charleston													Huntington	
Elevation, ft		Surface		260		490		710		1370		2430			2000	
Date	Time	Direction, degrees	Speed, mph	Direction, degrees	Speed, mph	Direction, degrees	Speed, mph	Direction, degrees	Speed, mph	Direction, degrees	Speed, mph	Direction, degrees	Speed mph	Time	Direction, degrees	Speed, mph
10-25	1700	245	9.4	243	10.3	230	10.4	222	10.1	236	11.7	228	12.4	1900	223	13
	1900	074	2.4	Calm	Calm	226	4.6	225	9.5	246	17.2	229	21.2			
10-26	1500	265	19.6	268	22.4	269	24.2	267	22.6	265	22.0	267	28.0	1900	229	10
	1700	299	4.0	298	8.6	283	12.2	276	17.6	275	23.4	273	21.0			
10-27	1500	290	8.8	286	10.2	279	12.0	277	14.0	284	10.0	264	8.0	1900	229	13
	1700	315	6.0	305	7.4	293	11.0	290	15.6	280	13.4	271	16.2			
10-28	1455	318	18.8	318	16.4	319	18.2	319	23.6	319	22.0	317	19.2	1900	229	24
	1700	323	7.6	327	11.6	328	16.2	328	21.2	328	24.4	M	M			
10-29	1500	065	2.8	105	2.3	160	3.3	164	3.4	125	4.2	140	5.6	1900	222	16
	1700	045	4.1	034	3.5	012	2.9	007	3.1	023	2.9	146	3.6			
10-30	1455	272	5.6	255	8.0	235	12.8	241	13.7	240	7.0	231	12.8	1900	229	3
	1700	263	5.3	250	6.6	242	9.4	245	10.0	230	9.8	225	14.0			
10-31	1500	268	33.6	272	35.2	266	25.0	265	21.0	263	34.0	267	42.0	1900	236	17
	1700	297	16.2	298	16.4	300	13.6	296	13.6	292	23.6	285	16.0			
11-01	1500	296	8.4	311	9.0	311	11.8	307	14.2	317	14.6	288	16.0	1900	229	16
	1700	313	8.9	314	10.2	307	14.0	301	15.6	289	14.8	289	23.4			
11-02	1500	207	1.2	262	1.7	274	4.2	274	4.1	220	3.5	208	5.7	1900	221	12
	1700	193	4.0	220	6.0	198	6.6	192	7.6	205	6.4	210	15.0			
11-03	1500	217	11.4	223	10.2	234	10.0	229	9.8	234	10.6	242	15.8	1900	223	20
	1700	202	6.0	217	7.6	217	7.8	224	6.6	234	10.2	232	12.0			
11-04	1505	232	7.6	268	8.2	271	9.8	274	12.0	279	12.4	279	9.8	1900	201	9
	1700	356	6.5	345	6.3	332	8.2	342	9.8	322	10.3	286	8.4			
10-25	2100	104	6.0	128	5.3	182	6.1	213	13.6	232	23.0	238	30.2			
10-26	0510	107	5.4	134	5.6	197	7.0	221	15.2	Fog	Fog	M	M	0700	226	15
	2100	099	4.1	122	4.4	211	5.6	261	11.6	275	14.4	292	16.0			
10-27	0500	096	1.9	190	2.1	247	6.4	267	9.7	309	13.4	M	M	0700	230	10
	2100	073	2.3	102	2.2	247	4.6	260	11.8	274	21.0	274	18.4			
10-28	0500	M	M	M	M	M	M	M	M	M	M	M	M	0700	225	33
	2100	358	3.0	010	7.0	011	12.0	015	15.4	019	21.6	012	19.6			
10-29	0511	106	5.2	111	4.5	094	3.9	076	8.6	093	13.8	M	M	0700	225	26
	2100	089	5.2	105	5.3	104	4.4	070	5.5	097	5.6	189	17.7			
10-30	0516	073	3.5	112	5.3	155	6.2	206	10.0	M	M	M	M	0700	210	17
	2100	090	6.2	122	6.2	184	8.0	221	14.0	245	23.8	239	25.0			
10-31	0455	093	4.3	215	3.4	215	11.6	221	19.8	M	M	M	M	0700	236	14
	2100	M	M	M	M	M	M	M	M	M	M	M	M			
11-01	0515	273	2.8	273	3.4	275	9.2	275	14.4	M	M	M	M	0700	233	12
	0523	310	1.4	278	3.5	282	11.8	288	16.0	M	M	M	M			
	2100	042	2.8	110	2.5	211	1.9	280	6.2	323	24.0	305	18.4			
11-02	0516	103	4.5	123	4.9	173	5.0	254	3.8	013	4.6	341	10.2	0700	236	2
	2100	105	6.7	121	6.0	161	11.8	213	16.0	232	20.2	247	31.6			
11-03	0512	105	5.7	116	5.0	200	6.8	221	15.7	252	26.1	M	M	0700	235	27
	2100	088	3.9	115	5.4	182	6.2	231	14.4	247	26.4	243	27.8			
11-04	0527	069	2.0	245	5.1	243	12.9	243	14.9	254	24.0	M	M	0700	226	24
	2100	053	3.9	060	5.0	058	6.0	049	8.0	054	17.8	063	9.2			
11-05	0533	080	2.9	126	2.5	151	1.7	095	5.1	173	15.6	M	M	0700	215	6

M = Missing data.

Temperature profile data obtained during each season are presented in Tables B-18 through B-21.

TETROON TRACKING

The few morning tetroon releases produced some very interesting illustrations of the complexity of circulation patterns in the Kanawha Valley. Notes taken during two of these runs have been rewritten and are included here along with information on an early evening run for comparison.

July 29, 1965: Release at 6:15 a.m., EST, from Kelly Works grounds and about 1/4 mile north of the Patrick Street Bridge. The tetroon rose and drifted over the Kelly Works Buildings, then descended to below river bank level while crossing the river. Drifting under the Patrick Street Bridge, the tetroon rose again, cleared the Arlan's store building, but descended again into the parking lot. Since the tetroon had a rather long cord attached and appeared to float at too low an elevation, a portion of the cord was cut off and the tetroon was released again. This time the tetroon continued southward across MacCorkle Avenue and up the hillside. The tetroon caught in a tree on the hillside; and since only 20 minutes had elapsed, staff members decided that a rescue would be attempted and another release made from this new point. Some time was required to approach the site, and the tetroon freed itself before staff members arrived. This time the tetroon continued on over the hill, and was grounded again on the lee slope of the hill a few minutes later. The tetroon had moved almost directly southward throughout the course of travel.

The Kanawha Valley at this point was free of fog although the Two-Mile Creek Valley, extending northward, was fog-filled.

The course followed and the related pibal and temperature data are plotted in Figure B-19.

July 30, 1965: Release at 6:43 a.m., EST, from Kelly Works grounds. The tetroon rose over the Kelly Works building, descended, and drifted under the Patrick Street Bridge. The tetroon was moving more slowly this time, however, and rose to an estimated 150 feet after crossing the river. The tetroon moved upstream above the river bank, changed elevation from perhaps 200 feet to near the river surface several times, and became trapped in an eddy of the air perhaps 1 1/2 miles upriver. The tetroon made two complete circuits in this eddy, moved at low level toward the hillside, rose to about 200 feet, drifted away from the hillside

Table B-18. TETHERSONDE DATA MEASURED AT CHARLESTON CITY HALL JANUARY 25-30, 1965

			Temperature at elevation (in feet) indicated,°F.									
Time	Date	Surface	50	100	150	200	300	400	500	600	700	800
2 a.m.	26	40.8	44.6	46.0	48.3	51.0	56.0	56.7	56.2	55.6		
	28	27.0	30.0	29.5	29.6	29.0	27.6	26.7				
4 a.m.	28	27.0	31.4	30.6	30.6	30.6	30.9	31.4				
6 a.m.	25	46.2	49.0	49.0	47.9	47.9	49.3	49.4	49.4	49.2		
8 a.m.	25	42.0	42.7	43.2	43.2	43.4	45.8	49.8				
10 a.m.	25	37.2	39.4	41.4	44.8	48.0	50.8	52.0	51.6			
	27	24.2	28.7	27.5	26.8							
12 a.m.	26	38.0	43.0	44.2	44.8	46.4	54.6	54.6	54.5	54.4		
	27	28.2	27.7	27.7	27.7	26.9	26.7	27.7				

Table B-19. TETHERSONDE DATA MEASURED AT NORTH CHARLESTON RECREATION AREA MAY 3-8, 1965

			Temperature at elevation (in feet) indicated, °F.									
Time	Date	Surface	50	100	150	200	300	400	500	600	700	800
4 a.m.	4	M	M	55.6	55.6	56.7	60.0	60.5	61.0	61.7		
	5	M	M	58.5	58.8	58.1	59.0	58.0	57.5	68.4	65.3	
8 a.m.	6	M	72.4	73.1	72.6	72.2	69.7	68.6				
	7	M	80.8	79.6	77.7	76.6	76.3	74.2	73.5	72.1	71.9	
	8	M	M	72.5	71.0	70.2	68.3	68.3	67.8	66.3	65.6	
10 a.m.	4	M	80.6	88.0	81.4							
	5	M	75.8	75.7	77.2	78.3						
2 p.m.	6	M	87.8	86.8	85.5	85.3	84.5	83.4	82.2	81.1	79.8	
4 p.m.	3	M	89.1	88.6	88.2	87.7	86.4	88.8				
	6	M	87.8	86.9	86.5	86.6	84.6	84.9	83.6			
	7	M	88.1	87.3	86.5	85.0	84.2	81.9	80.7	79.7	78.4	
6 p.m.	6	M	83.8	83.7	83.6	83.5	82.8	82.3	81.8			
	7	M	83.8	83.2	82.6	81.6	80.7	80.2	79.5	78.6		
8 p.m.	6	M	70.5	72.0	72.5	73.4	73.4	75.2	75.2	74.3	74.0	
	7	M	M	70.6	70.5	69.1	71.3	73.5	76.0	73.5		
10 p.m.	5	M	63.4	63.0	63.0	62.9	63.2	63.8				

M = Missing data.

Table B-20. TETHERSONDE DATA MEASURED AT THE KELLY WORKS OF TRU-TEMPER CORPORATION IN NORTH CHARLESTON - JULY 27-31, 1965

			Temperature at elevation (in feet) indicated, °F.									
Time	Date	Surface	50	100	150	200	300	400	500	600	700	800
4 a.m.	29	M	63.2	63.9	63.9	63.9	64.7	65.4	65.4	64.7		
	30	M	54.8	56.1	56.1	56.0	55.5	55.5	55.5	56.0		
	31	M	57.8	58.1	58.0	58.1	57.7	57.9	58.2			
6 a.m.	28	M	M	62.8	60.6	60.6	60.4	58.9	58.1			
	29	M	60.5	62.3	62.2	61.5	61.6	61.9	61.7	61.6		
	30	M	55.0	56.1	55.9	55.9	55.5	54.9	54.7	54.9		
	31	M	57.5	57.5	57.6	57.5	57.5	57.5	57.9			
8 a.m.	28	M	70.3	70.2	69.5	M	M	M	M	M	66.3	
	29	M	66.5	65.8	65.8	65.7	64.3	63.3	63.5	62.4		
	30	M	62.3	62.1	61.3	60.1	59.5	58.2	58.0	58.0	58.0	58.0
	31	M	63.0	62.6	62.4	62.0	61.7	60.9	60.7			
10 a.m.	28	M	78.9	78.4	78.6	77.7	77.7	76.9	76.3	75.7	74.5	74.5
	29	M	74.8	74.2	73.5	73.5	73.5	73.4	73.0	72.4		
	30	M	65.1	64.9	64.7	64.9	64.7	63.1	62.2	60.6	61.3	60.8
	31	M	73.0	72.1	72.2	72.4	71.4	70.9	70.4			
4 p.m.	27	M	79.0	79.5	79.2	78.9	78.6	78.4	78.1	78.0		
	28	M	83.4	82.5	82.4	81.8	81.1	80.2	79.9	78.9		
	29	M	79.1	79.3	78.5	78.0	76.4	76.0				
	30	M	80.5	80.2	80.0	79.2	78.0	77.9	78.0	77.4	77.3	76.3
6 p.m.	27	M	74.9	75.5	74.9	74.2	74.0	73.6	73.0	71.6		
	28	M	78.6	78.2	77.6	77.2	77.2	76.8	76.7	76.5		
	29	M	78.1	77.7	77.5	77.2	76.5	76.8				
	30	M	78.3	77.8	78.5	78.1	77.1	76.3	76.2			
8 p.m.	27	M	73.0	76.8	76.8	76.6	76.0	76.1	75.6			
	28	M	71.5	74.0	74.2	74.0	74.5	74.7	74.6	74.2		
	29	M	66.6	69.5	71.1	71.1	71.5	71.9	71.3	70.5		
	30	M	68.0	71.8	72.6	72.7	72.6	72.6	73.1	73.9	74.3	
10 p.m.	27	M	70.6	72.1	72.8	73.0	73.2	72.6	73.0			
	28	M	71.1	71.4	71.3	70.4	72.1	71.6	71.0	71.4	73.0	
	29	M	64.8	64.9	66.3	66.6	65.7	65.3	65.2	65.1	65.0	
	30	M	63.3	66.2	66.2	67.4	66.2	66.2	66.2			

M = Missing data.

Table B-21. TETHERSONDE DATA MEASURED AT NORTH CHARLESTON RECREATION AREA OCTOBER 26-NOVEMBER 5, 1965

		Temperature at elevation (in feet) indicated, °F.										
Time	Date	Surface	50	100	150	200	300	400	500	600	700	800
4 a.m.	28	51.0	52.0	53.5								
	30	56.2	57.1	58.1	58.8	59.5	59.5	59.5	62.4	68.0		
	01	55.0	55.7	60.0	60.6	61.1	61.5	61.5				
	02	50.8	52.5	55.0	55.0	55.0	55.4	55.3	55.9			
	03	57.8	59.5	59.6	59.8	59.9	60.1	65.2	71.3	73.0	75.9	
	04	47.4	51.0	54.0	58.5	60.1	61.2	61.9	61.8	61.0	61.0	
6 a.m.	27	43.0	45.5	47.0	47.3	47.4	46.2	48.8	50.4	51.2	51.5	
	28	42.0	43.0	43.0								
	29	60.0	60.4	58.8	56.6	54.6	56.0	58.8	57.1	54.7		
	30	60.0	61.5	62.5	62.8	63.0	63.0	63.3	67.0	71.8	75.1	
	31	58.6	60.5	61.1	61.9	62.9	67.0	70.8	72.0			
	01	32.0	33.5	39.5	39.5	39.6	41.0	41.0	39.8	39.5		
	02	48.7	49.0	51.0	51.3	51.4	49.8	49.0				
	03	62.0	63.5	65.0	65.8	66.6	67.0	67.8	75.6	80.5		
	04	62.5	64.5	68.5	69.5	71.0	71.7	72.5	72.5	72.5	71.5	
	05	57.0	58.2	60.0	60.0	60.5	61.0					
8 a.m.	27	43.0	43.5	43.5								
	28	69.5	69.0	69.0	68.8	68.5	68.6	70.8				
	29	M	M	M	M	M	51.4	51.8	49.9	48.9	48.2	
	30	36.5	37.1	38.5	38.5	38.5	38.0	39.3	44.8	50.3	53.5	
	31	59.9	64.5	67.6	69.1	70.5	71.5	72.3	72.0	72.0		
	01	63.1	65.5	66.0	66.0	66.0	68.0	68.0	66.6	63.0	65.7	
	02	59.9	60.0	61.0	61.0	61.0	61.6	62.2	63.8	61.0	70.4	
	03	62.0	63.5	64.5	64.5	64.6	66.5	75.1	78.5	79.1	79.5	
	04	59.0	61.0	64.5	67.0	61.5	69.2	69.5	69.5	69.5	69.5	
	05	57.2	58.5	59.0	59.0	59.0	58.5	59.2	61.2	63.9	65.7	
10 a.m.	26	46.0	48.0	48.0	48.5	49.0	48.8	48.8	49.1	49.5	48.7	
	27	55.0	54.0	53.4	53.2	53.0	53.0	52.5	52.1	52.4	53.2	
	28	61.0	61.0	60.0	59.7	59.5	59.2	58.8	58.2	59.6	60.9	
	29	43.0	43.0	43.0	43.3	43.5	43.5	43.4	42.5	42.6	43.0	
	30	44.0	45.0	45.5	47.0	48.0	48.0	50.0	50.5	51.9	51.6	
	01	57.0	57.0	57.0	57.0	57.0	57.0	57.0	56.9	56.5	57.0	
	02	62.1	61.0	61.0	61.3	61.5	62.0	62.1	63.6	65.1	65.7	
	03	57.2	58.0	60.5	61.1	61.6	62.2	62.5				
	04	68.0	68.3	67.7	61.8	67.0						
	05	59.9	60.5	60.0	60.0	60.0	60.5	61.6	62.5	62.8	64.2	

M = Missing data.

Table B-21 (continued). TETHERSONDE DATA MEASURED AT NORTH CHARLESTON RECREATION AREA - OCTOBER 26-NOVEMBER 5, 1965

		Temperature at elevation (in feet) indicated, °F.										
Time	Date	Surface	50	100	150	200	300	400	500	600	700	800
4 p.m.	29	51.0	51.0	51.0	50.5	50.0	49.5	49.5	49.4			
	30	66.0	66.0	66.0	65.4	64.9	64.4	64.0	63.0	63.0	62.3	
	02	61.8	61.4	61.0	61.0	61.0	60.5	60.0	59.9	58.9	58.0	
	03	73.0	73.4	72.5	72.3	72.0	72.0	71.7	71.2	70.5	70.3	
	04	69.5	69.5	69.0	68.9	68.4	68.0	67.4				
6 p.m.	26	51.0	52.5	58.1	59.2	60.0	60.5	59.9	59.5	59.1	58.5	
	27	52.7	53.5	56.6	57.4	58.5	58.5	58.4	57.8	57.5	57.5	
	29	44.2	44.0	47.0	49.5	51.0	51.0	50.5	50.5	50.5	50.0	
	30	49.6	54.5	57.0	57.6	58.5	M	M	60.5	60.5	60.5	
	01	45.0	48.0	51.1	51.9	51.5	51.3	51.0	51.0	50.4	50.0	
	02	49.0	49.1	51.9	56.3	57.5	58.8	60.5	60.5	60.5	60.5	
	03	58.0	61.5	65.5	65.6	67.1	68.5	68.5	68.6	68.9	68.9	
	04	63.5	63.0	63.0	63.4	63.0	63.0					
8 p.m.	25	36.5	41.0	41.5	42.0	42.2	44.6	46.1	46.7	47.0	47.5	
	26	48.0	52.0	53.5	54.5	55.0	55.6	57.5	58.0	58.1	58.6	
	27	44.0	45.5	48.5	49.0	49.3	50.0	51.5	53.0	53.7	54.0	
	29	35.0	36.5	39.5	40.5	41.0	41.5	42.5	43.5	45.1	46.0	
	30	40.5	44.5	45.8	48.5	48.5	49.7	53.5	55.9	57.3	57.5	
	01	40.0	43.5	45.5	46.5	46.5	47.0	49.0	49.9	49.0	49.0	
	02	41.0	47.5	48.5	49.0	49.1	50.9	53.9	55.3	57.5		
	03	49.0	54.5	56.0	57.5	57.6	58.9	63.6	66.0	66.2	67.2	
	04	51.0	55.0	56.2	58.1	58.5	58.5	58.5	57.9	57.0	57.4	
10 p.m.	25	34.0	37.5	38.0	38.0	38.1	39.4	43.2	45.4	46.3		
	26	M	39.5	44.5	44.5	44.5	45.0	44.6	50.4	51.7	52.4	
	27	40.0	43.5	45.0	45.0	45.0						
	29	29.0	32.5	32.5	32.5	33.0	33.0	33.5	40.8	41.4	42.5	
	01	39.0	41.0	45.0	45.5	45.5	46.0	46.2	49.5	52.1	52.5	
	02	36.6	41.0	42.1	42.5	42.5	42.7	45.2	52.3	56.4	58.3	
	03	43.9	50.6	51.5	51.5	52.3	54.9	59.6	61.6	63.2	63.4	
	04	48.0	52.5	55.1	56.1	56.5	56.0	56.0	56.0	55.7	56.3	

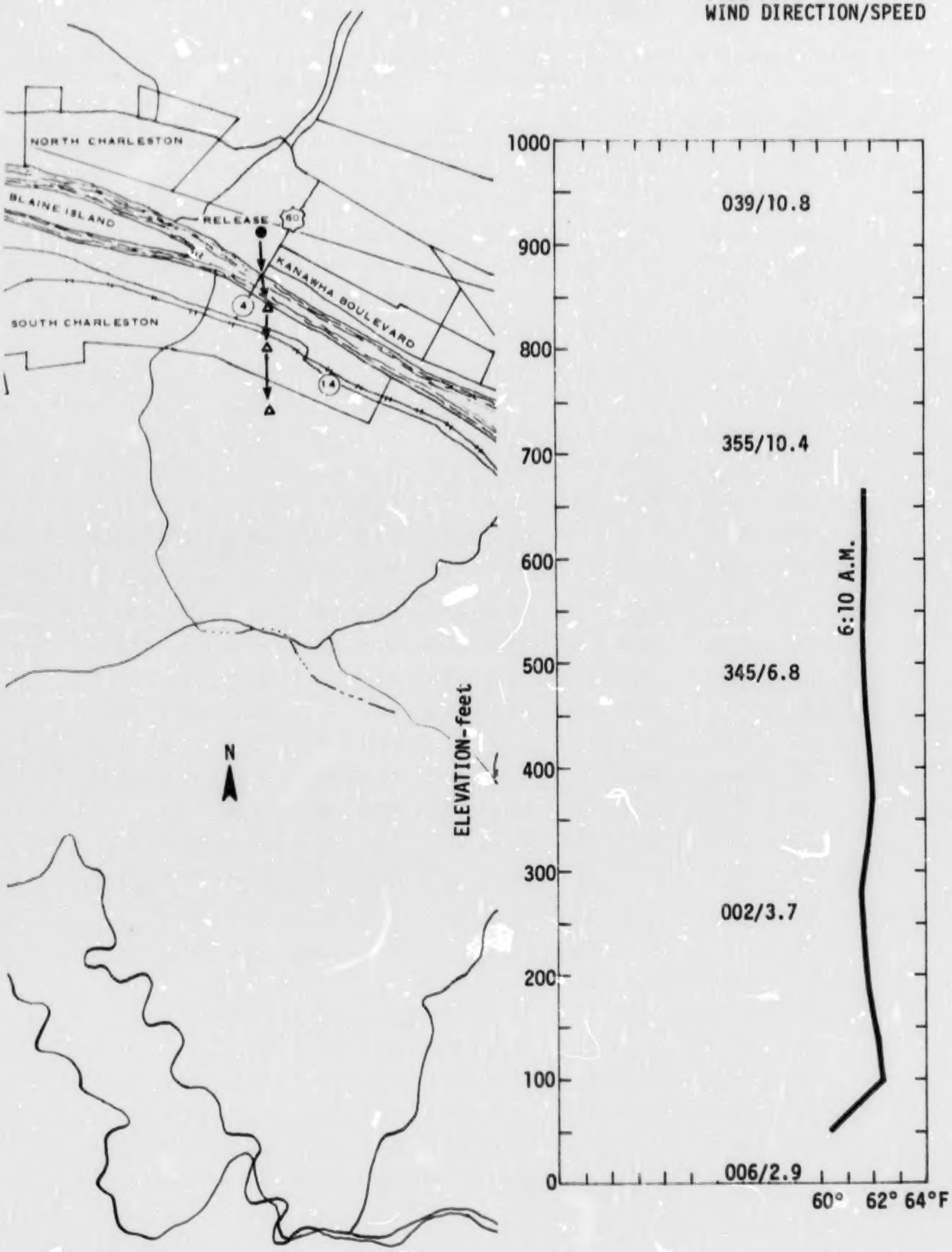

7:08 A.M.
WIND DIRECTION/SPEED
NORTH CHARLESTON
BLAINE ISLAND
RELEASE
60
4
KANAWHA BOULEVARD
SOUTH CHARLESTON
14
N
ELEVATION-feet
1000
900
800
700
600
500
400
300
200
100
0
039/10.8
355/10.4
345/6.8
002/3.7
006/2.9
6:10 A.M.
60°
62°
64°F

Figure B-19. Tetroon run on July 29, 1965 from 6:15 to 7:10 a.m.

again, and sank above the river. On the third circuit the tetroon drifted under a tree on the hillside and was trapped. The tetroon was retrieved, and about 2 feet of cord was cut off. The tetroon was released again with a toss, and escaped the eddy, rose now to several hundred feet, drifted back downstream above the hillside and descended again out of sight almost 2 hours after release and only about a mile distant from the release point.

The valley was filled with patchy haze during this run, and several times the tetroon disappeared briefly in the haze. At the time of release, smoke plumes were seen to be rising vertically.

The course of the tetroon and related pibal and temperature data are plotted in Figure B-20.

May 7, 1965: Released at 6:21 p.m. from the North Charleston Recreation Area. The tow balloon separated at an estimated 200 feet above the New York Central Tracks while on a south-southwest course. The tetroon had reached a stable elevation of perhaps 300 feet at the river and continued south over the south approach to the Patrick Street Bridge. Approaching the Chesapeake and Ohio Railway, the tetroon began to climb and move more easterly toward the rim of the valley. Moving slowly southward, the tetroon passed over the ridge in Vandalia at 100 feet, brushed a tree in Oakwood still moving south.

The tetroon appeared to sink slightly over valleys and brushed trees on several ridges until the device sank onto the lee side of a ridge and was trapped beneath tree limbs on the south side of a tree in the Middle Ridge School Area.

The course of the tetroon and the related pibal and temperature data are plotted in Figure B-21.

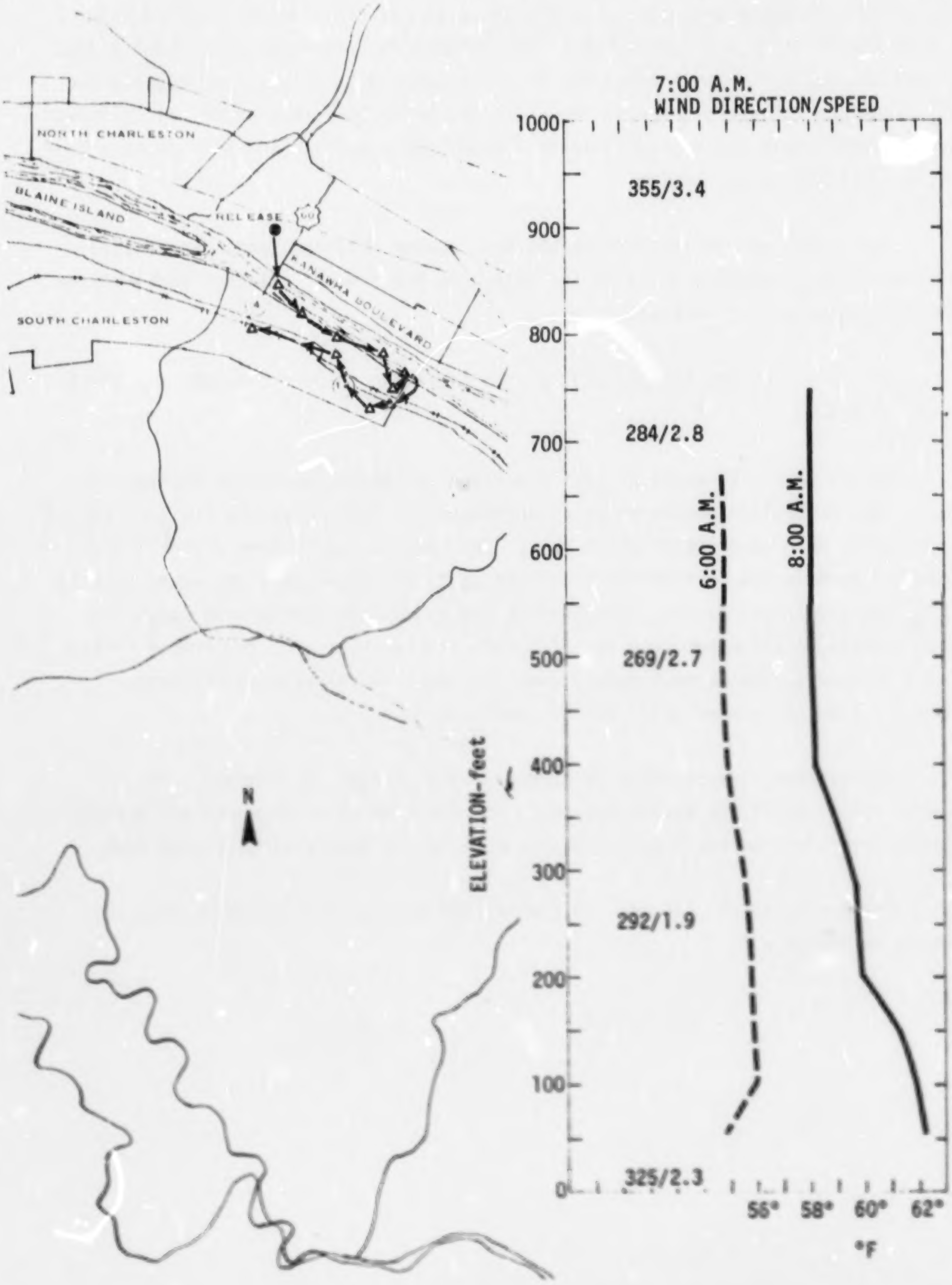


Figure B-20. Tetroon run on July 30, 1965, from 6:43 to 8:40 a.m.

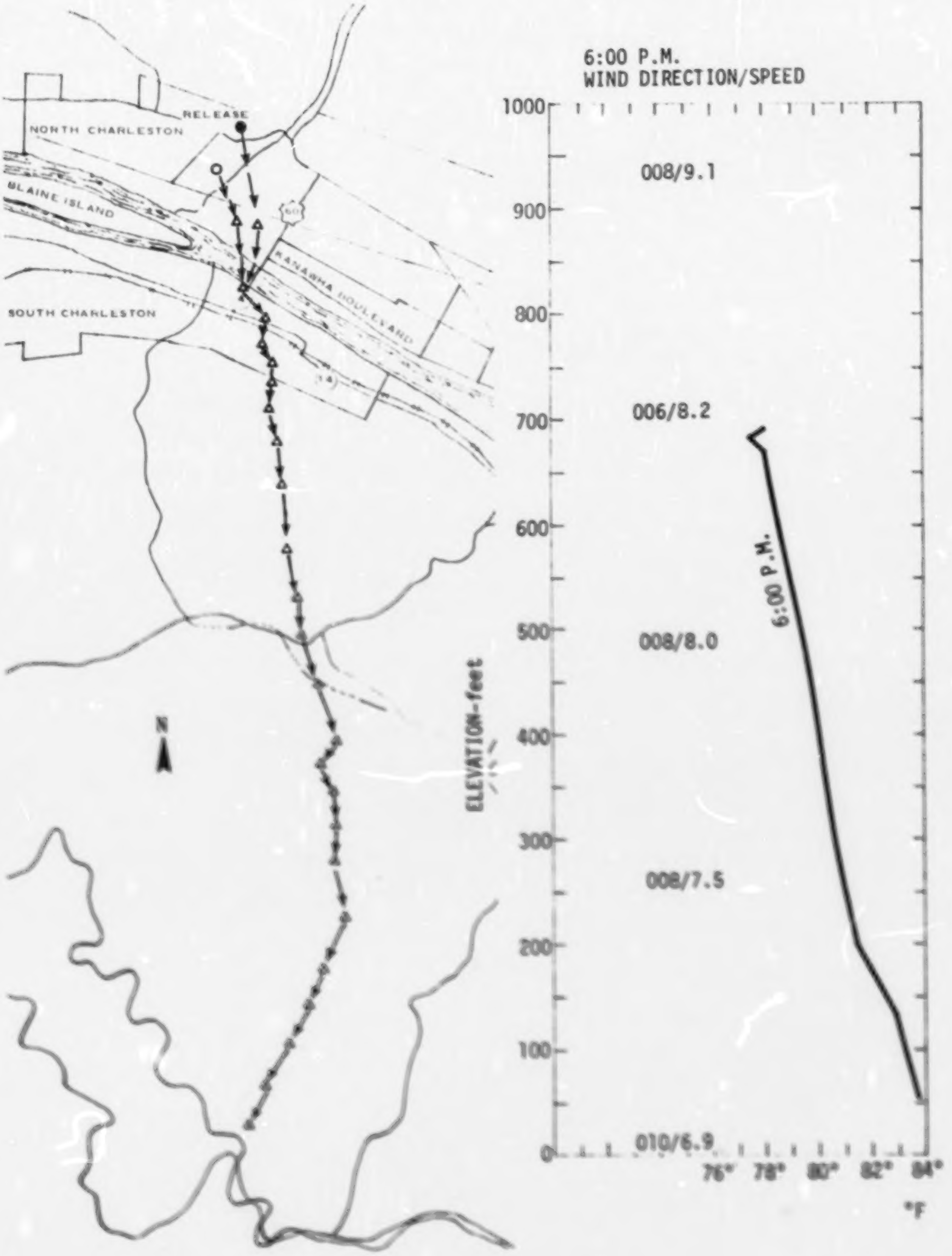


Figure B-21. Tetroon run on May 7, 1965, from 6:21 to 7:25 p.m.

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APPENDIX C. EMISSION FACTORS

The emission factors utilized in this report are listed in Tables C-1 through C-13 and were obtained in "A Compilation of Air Pollution Emission Factors for Combustion Processes, Gasoline Evaporation and Selected Industrial Processes," by Martin Mayer, Division of Air Pollution, U. S. Public Health Service. These emission factors were considered to be the best available for use during the preparation of the air pollution emission inventory. Expanded studies of air pollutant emissions will provide additional information for the development of new, more accurate emission factors in the near future. The factors reported here should be used with this in mind.

Table C-1 - Combustion of Coal - Gaseous Pollutants
Table C-2 - Combustion of Coal - Particulate Pollutants
Table C-3 - Combustion of Fuel Oil
Table C-4 - Combustion of Natural Gas
Table C-5 - Automotive and Diesel Exhaust Emissions
Table C-6 - Emissions Factors for Aircraft Below 3500 Feet
Table C-7 - Emissions Factors from Metallurgical and Mineral Processing
Table C-8 - Emissions Factors for Hot Asphalt Batching Plants
Table C-9 - Emissions Factors for Concrete Batching Plants
Table C-10 - Emissions Factors for Burning of Wood Waste
Table C-11 - Incineration of Refuse
Table C-12 - Open Burning of Refuse
Table C-13 - Gasoline Evaporation Emissions
Method for calculating domestic fuel use from U.S. Bureau of Census Data

Table C-1. COMBUSTION OF COAL - GASEOUS POLLUTANTS[a]
(lb/ton of coal burned)

Pollutant	Power plants	Industrial	Domestic and commercial
Aldehydes (HCHO)	0.005	0.005	0.005
Carbon monoxide	0.5	3	50
Hydrocarbons (CH_4)	0.2	1	10
Oxides of nitrogen (NO_2)	20	20	8
Oxides of sulfur (SO_2)	38 S[b]	38 S[b]	38 S[b]

[a] Reference 14.

[b] S equals percent sulfur in coal.

Example: If the sulfur content is 2 percent, the oxides of sulfur emission would be 2 x 38, or 76 lb. of sulfur oxides/ton of coal burned.

Table C-2. COMBUSTION OF COAL PARTICULATE POLLUTANTS

Type of unit	Particulate emission,[a] lb/ton of coal burned	Benzo(a)pyrene emission,[b] μg/ton of coal burned
Pulverized - general	16A[c]	600
Dry bottom	17A[c]	
Wet bottom		
Without reinjection	13A[c]	
With reinjection	24A[c]	
Cyclone	2A[c]	6,000[d]
Spreader stoker		700
Without reinjection	13A[c]	
With reinjection	20A[c]	
All other stokers	5A[c]	100,000
Hand-fired equipment	20	12×10^6

[a] Reference 1.

[b] Reference 2.

[c] A equals percent ash in coal.

Example: If the percent ash in the coal is 10 percent, the ash emission for a cyclone unit would be 2 x 10 or 20 lb/ton of coal burned.

Table C-3. COMBUSTION OF FUEL OIL[a]
(lb/1000 gal. of oil burned[b])

Pollutants	Large sources (1000 h.p. or more)	Small sources (1000 h.p. or less)
Aldehydes	0.6	2
Benzo(a)pyrene[c]	5000 μg/1000 gal	40,000 μg/1000 gal
Carbon monoxide	0.04	2
Hydrocarbons	3.2	2
Oxides of nitrogen (NO_2)	104	72
Sulfur dioxide	157 S[d]	157 S[d]
Sulfur trioxide	2.4 S[d]	2 S[d]
Particulate	8	12

[a] Reference 4.

[b] Density of fuel oil equals 8 lb/gallon and there are 42 gallons per barrel.

[c] Reference 2.

[d] S equals percent sulfur in oil.

Example: If the sulfur content is 2 percent, the sulfur dioxide emission would be 2 x 157, or 314 lb. SO_2/1000 gal oil burned.

Table C-4. COMBUSTION OF NATURAL GAS[a]
(lb/10^6 ft^3 of natural gas burned)

Pollutants	Power plants	Industrial boilers	Domestic and commercial heating units
Aldehydes	1	2	negligible
Benzo(a)pyrene[b]	n.a.[c]	20,000 μg/10^6 ft^3	130,000 μg/10^6 ft^3
Carbon monoxide	negligible	0.4	0.4
Hydrocarbons	negligible	negligible	negligible
Oxides of nitrogen	390	214	116
Oxides of sulfur	0.4	0.4	0.4
Ammonia	n.a.[c]	0.3[d]	0.3[d]
Organic acids	n.a.[c]	62[d]	62[d]
Particulate	15	18	19

[a] Reference 5.

[b] Reference 2.

[c] Not available.

[d] Reference 6.

Table C-5. AUTOMOTIVE AND DIESEL EXHAUST EMISSIONS
(lb/1000 gal)

Pollutant	Gasoline engines[a]	Diesel engines[b]
Aldehydes	4	10
Benzo(a)pyrene	0.3 gram/1000 gal[c]	0.4 gram/1000 gal[d]
Carbon monoxide	2910	60[a]
Hydrocarbons	524[e]	180
Oxides of nitrogen	113	222[f]
Oxides of sulfur	9	40
Ammonia	2[f]	n.a.[g]
Organic acids	4[f]	31[f]
Particulates	11	110

[a] Includes blowby emissions, but not evaporation losses 7.

[b] Reference 8.

[c] Reference 9.

[d] Reference 10.

[e] Includes 128 lb/1000 gal blowby emissions 11.

[f] Reference 6.

[g] Not available.

Table C-6. EMISSION FACTORS FOR AIRCRAFT BELOW 3500 FEET
(lb/flight)[a]

Type of emission	Jet[b,c]	Turboprop[d]		Piston[c]	
	4 engines	2 engines	4 engines	2 engines	4 engines
Aldehydes	4	0.3	1.1	0.2	0.5
Carbon monoxide	35	2.0	9.0	74.0	245.0
Hydrocarbons	10	0.3	1.2	15.0	49.0
Oxides of nitrogen	23	1.1	5.0	4.4	15.0
Particulates	34	0.6	2.5	0.4	1.2

[a] A flight is the combination of a landing and a takeoff.

[b] No water injection on takeoff.

[c] Reference 12.

[d] Reference 13.

Table C-7. EMISSION FACTORS FROM METALLURGICAL AND MINERAL PROCESSING[a]

Process	Aerosol emission factor, lb/ton of raw material processed	
	Uncontrolled	Controlled
Gray iron melting cupolas (avg.)	17.1	0.26[b]
Less than 48" I.D.	12.9	-
48-60" I.D.	19.5	-
Greater than 60" I.D.	18.9	-
Electric steel melting furnaces (avg.)	8.6	0.17[b]
Less than 5-ton capacity	10.6	-
5- to 20-ton capacity	5.7	-
50- to 75-ton capacity	9.6	-
Melting of red brass (7% zinc)		
Crucible or pot furnaces	3.3	-
Rotary furnaces	21.3	10.1[c]
Reverberatory furnaces	16.8	-
Electric furnaces	3	-
Melting of yellow brass (20% zinc)		
Crucible furnaces	14	5.1[c]
Rotary furnaces	-	22.8[c]
Reverberatory furnaces	-	5.7[b]
Electric induction type furnaces	0.7	-
Melting of bronze		
Crucible furnaces	3.8	-
Rotary furnaces	30.6	4.7[b]
Melting of aluminum		
Crucible furnaces	1.9	-
Reverberatory furnaces	5.2	2.1[d]
Glass furnaces (recuperative)	3.4	-

[a] Reference 5.

[b] With baghouse control.

[c] Slag cover used as the only control method.

[d] With packed column scrubber and either baghouse or electrostatic precipitator as secondary collector.

Table C-8. EMISSION FACTORS FOR HOT ASPHALT BATCHING PLANTS[a]

Particulate emission factor, lb/ton of product	
Uncontrolled	Controlled[b]
5.0	0.2

[a] Reference 14.

[b] Scrubbers of the multiple centrifugal or baffled spray tower type.

Table C-9. EMISSION FACTORS FOR CONCRETE BATCHING PLANTS[a]

Particulate emission factor, lb/yd of concrete	
Uncontrolled	Controlled
0.2	0.025

[a] Reference 15.

Table C-10. EMISSION FACTORS FOR BURNING OF WOOD WASTE[a]

Pollutants	lb/1000 lb wood waste
Sulfur dioxide	0.08
Oxides of nitrogen	0.06
Hydrocarbons	10.0
Organic acids	0.2
Aldehydes	0.9
Particulates	10.0[b]

[a] Reference 16.

[b] Reference 17.

Table C-11. INCINERATION OF REFUSE
(lb/ton of refuse burned)

Pollutant	Municipal multiple chamber[a]	Industrial and commercial[b]	
		Single chamber	Multiple chamber
Aldehydes	1.1	5-64	0.3
Benzo(a)pyrene[c]	6,000 μg/ton	100,000 μg/ton	500,000 μg/ton
Carbon monoxide	0.7[d]	20-200[c]	0.5
Hydrocarbons	1.4	20-50[c]	0.3
Oxides of nitrogen	2.1	1.6[c]	2.0[h]
Oxides of sulfur	1.9	n.a.[g]	1.8[h]
Ammonia	0.3	n.a.	n.a.
Organic acids	0.6	n.a.	n.a.
Particulate	6[e];12[f]	20-25	4

Pollutant	Flue-fed apartment incinerator[i]	Domestic single chamber	
		Without auxiliary gas burning[k]	With auxiliary gas burning[i]
Aldehydes	5	6	2
Benzo(a)pyrene[c]	n.a.	n.a.	n.a.
Carbon monoxide	n.a.	300	n.a.
Hydrocarbons	40[j]	100	1.5
Oxides of nitrogen	0.1	1.5	2
Oxides of sulfur	0.5	2.0	2
Ammonia	0.4	0.4	negligible
Organic acids	22	13	4
Particulate	26	39	6

[a] Reference 18.
[b] Reference 19.
[c] Reference 2.
[d] Reference 20.
[e] For incinerator with spray chamber, references 20-27.
[f] For incinerator without spray chamber, references 20-22, 25-29.
[g] Not available.
[h] Reference 30.
[i] References 28.
[j] References 22, 25, 27.
[k] References 19, 22, 25, 28.

Table C-12. OPEN BURNING OF REFUSE
(lb/ton of refuse burned)

Pollutants	Burning dump[a,b]	Backyard burning[c]
Aldehydes	4	3.6
Benzo(a)pyrene[d]	250,000 µg/ton	350,000 µg/ton
Carbon monoxide	n.a.[e]	n.a.
Hydrocarbons	280.0	280.0
Oxides of nitrogen	0.6	0.5
Oxides of sulfur	1.2	0.8
Ammonia	2.3	1.6
Organic acids	1.5	1.5[f]
Particulate	47.0	150[g]

[a] Three pounds per capita per day of refuse burned is assumed.

[b] Reference 25.

[c] Reference 29.

[d] Reference 2.

[e] Not available.

[f] References 25,28,29,31.

[g] Reference 28.

Table C-13. GASOLINE EVAPORATION EMISSIONS

Source	Hydrocarbon Emissions	
	lb/1000 gal of throughput	Percent loss, by volume[a]
Storage tanks[b,c]		
Cone roof	47.0	
Floating roof	4.8	
Filling tank vehicles[d]		
Splash fill	8.2	0.14
Submerged fill	4.9	0.08
50% splash and 50% submerged fill	6.4	0.11
Filling service station tanks[c,e]		
Splash fill	11.5	0.19
Submerged fill	7.3	0.12
50% splash and 50% submerged fill	9.4	0.15
Filling automobile tanks[f]	11.6	0.19
Automobile evaporation losses[g] (gas tank and carburetor)	920.0	1.50

[a] An average gasoline specific gravity of 0.73 is assumed.
[b] Reference 32.
[c] Reference 33.
[d] Reference 34.
[e] Reference 35.
[f] Reference 36.
[g] Reference 11.

Appendix C-1. Questionnaires

1. Industrial Questionnaire
(Large plants)

Names and Address

Name and Title of Person to Contact Regarding this Report	Telephone Number

Return completed copies of questionnaire to:

Mr. Carl G. Beard, II
Project Director
Kanawha Valley Air Pollution Study
1724 Washington Street, E.
Charleston 1, West Virginia

I. General Information - Use 1963 Data
   A. Manufacturing Activities
      1. Days per week normally in operation
      2. Days per year normally in operation
      3. Number of shifts per day in normal operation
      4. Total number of employees at this establishment
   B. Meteorological Information
      1. Do you record any of the following meteorological information on a routine basis:

Wind Speed & Direction	Humidity
Temperature	Other Specify

      2. Can the meteorological information listed in B-1 be made available to Governmental Agencies?

Yes No

II. Process operations Parcel

Use 1963 Data

A. Principal Products

Products	Amount Produced* (tons/year) or equivalent (or see code below)	Specify months/year usually in production	Established program of maintenance checks on air pollution control equipment		
			Yes	No	Not applicable

Product amount code (tons/year)

If you do not wish to disclose the amount produced, please insert appropriate range in above table.

(A) less than 1,000 (B) 1,000 to 10,000 (C) 10,001 to 100,000
(D) 100,001 to 200,000 (E) more than 200,000

*Where production cannot be reasonably expressed in tons/year, designate units of production and amount or applicable range (i.e., A,B,C, etc.).

Parcel

B. List specific material emitted to atmosphere from process operations.

Material	Amount (lb/day)	Air pollution* control equipment (see Code A below)	Efficiency actual or estimated percent	Stack height (ft)

*Where two sources emit the same material to the atmosphere, separate the different types of control equipment, efficiencies and stack heights by slash marks.

Example: Material from two sources: the first through a scrubber with 60 percent efficiency, then up a 100-foot stack; the second through an adsorption unit with 95 percent efficiency, then up a 30-foot stack - Column, Air Pollution Control Equipment, 09/13; Column, Efficiency, 60/95; Column, Stack Heights, 100/30.

Code A - Air Pollution Control Equipment Presently in Use:

01 None
02 Settling chamber
03 Electrostatic precipitator
04 Cloth filter
05 Absorption unit
06 Direct-fired afterburner
07 Catalytic afterburner
08 Demister
09 Scrubber
10 Cyclone
11 Multicyclone
12 Other powered inertial separators
13 Adsorption unit
14 Condenser
15 Other (Describe)

Parcel

C. For material not specifically identified and reported in Item B above, please indicate the amount of process emissions in appropriate category:

1. Emission of Organic Material (List amount in lb/day).

	Aromatic		Olefinic		Aliphatic	
Classification	Gas or vapor	Solids	Gas or vapor	Solids	Gas or vapor	Solids
Hydrocarbons						
Alcohols						
Aldehydes						
Amines						
Acids						
Ethers						
Epoxides						
Halides						
Ketones						
Acid derivatives						
Sulfur compounds						
Organometallic						
Other (specify)						

Aromatic - organic compounds containing a benzene structure

Olefinic - organic compounds consisting of unsaturated aliphatic hydrocarbons, including compounds with double and triple bonds.

Aliphatic - organic compounds with carbon atoms arranged in a chain-like structure, excluding unsaturated compounds.

2. Emission of Inorganic Materials Parcel

Gases		Solids and mists	
Classification	Amount (lb/day)	Classification	Amount (lb/day)
Ammonia		Sulfuric acid	
Sulfur dioxide		Hydrochloric acid	
Sulfur trioxide		Nitric acid	
Hydrogen sulfide		Phosphoric acid	
Carbon disulfide		Calcium oxide	
Carbon monoxide		Sodium carbonate	
Nitrogen oxides		Acids (n.o.s.)	
Chlorine		Oxides (n.o.s.)	
Fluorine		Hydroxides	
Bromine		Nitrates	
Chlorides		Chlorides	
Fluorides		Fluorides	
Bromides		Bromides	
Phosphorus compounds		Sulfides	
Cyanide compounds		Sulfates	
Other (specify)		Carbonates (n.o.s.)	
		Phosphates	
		Silicates	
		Silicon compounds (n.o.s.)	
		Sulfur	
		Metallic fume	
		Other (specify)	

n.o.s. - not otherwise specified.

III. Combustible Waste Disposal Parcel

Waste material		Method of disposal	Incinerator used capacity	Auxiliary fuel used
Type of waste (A)	Amount per year (B)	(See code below)	(lb/hr)	(C)

Method of Disposal Code:

01 - Open burning in pit, dump, etc. on plant premise.

02 - Hauled to dump on plant premise, not burned.

03 - Picked up by private salvage or waste disposal company.

04 - Picked up by municipality.

05 - Burned in boiler or furnace.

06 - Incinerator, single chamber (one totally enclosed refractory-lined chamber in which both primary and secondary combustion take place).

07 - Incinerator, multiple chamber (two or more refractory-lined chambers interconnected by gas passage parts or ducts and designed in such a manner as to provide for complete combustion of materials).

08 - Incinerator, rotary.

09 - Wigwam waste burner.

10 - Other (specify)

(A) Example of type of waste - organic residues, tars, solvents, paper, garbage, etc.

(B) Example of units - tons, pounds, gallons, cubic feet, cubic yards, etc.

(C) Indicate whether auxiliary fuel is used in incinerators and pit burning.

IV. Combustion Processes for Heat and Power Parcel

Total Fuel Used

Type Grade

Supplier: Captive External Both

If coal: Ash % (dry basis) Sulfur % (dry basis)

If liquid: Sulfur % If gas: Sulfur %

Estimate of fuel consumed monthly: Cubic feet

Gallons tons

Fly Ash Parcel

Tons collected per month

Disposal after collection, slurry or dry

If dry: Is percentage of ash removed by other persons? %.

List location of major dry disposal areas.

A. Boilers

No.	On stack number	Operating or standby	Amount of fuel used tons/day	type (stoker, pulverized fuel, other)

B. Boiler Stacks and Stack Gases Parcel

Stack number	Location	Height	Top inside diameter	Exit velocity	Exit temperature	Gas volume (ft^3/min)	Particulate loading (grains/ft^3)

C. Air Pollution Abatement Devices

	Primary				Secondary			
On stack number	Type	Efficiency	Date of efficiency listed*	Date devices installed*	Type	Efficiency	Date of efficiency listed*	Date equipment installed*

*Efficiency data quoted is to be last survey or, if not available, give data when installed. Efficiency data should be given in terms of weight and particle size, if available.

Do you have an established program of operational maintenance checks on your air pollution control devices?
(Check one) Not applicable Yes No

Approximately what dollar amounts have you spent on air pollution control devices and operation during the past 15 years.

1. Equipment (Total for 15 years)
2. Operations (Total for 15 years)

Parcel

D. Type of melting furnace(s) used: (Check all applicable).

1. None
2. Pot or crucible
3. Cupola
4. Electric arc
5. Electric induction
6. Reverberatory
7. Rotary
8. Glass furnace
9. Others
   (Specify)

E. Other equipment or operations: (Check all applicable)

1. Air blowing (agitation, chemical reactions, etc.)
2. Dryers
3. Kilns
4. Solids handling and processing (pneumatic conveying, sizing, grinding, etc.)

F. Air pollution control equipment presently in use in process operations: (insert number of operating units in parcel including those indicated in Item B).

1. Settling chamber
2. Electrostatic precipitator
3. Cloth filters
4. Absorption unit
5. Direct-fired afterburner
6. Catalytic afterburner
7. Demister
8. Adsorption unit
9. Scrubber
10. Cyclone
11. Multi-cyclone
12. Other powered inertial separators
13. Vapor recovery systems
14. Boilers (used as waste gas burners)
15. Others:
    (Specify)

APPENDIX C

Appendix C-1. Questionnaires

2. Industrial Questionnaire
(Small Plants)

Name and Address

Do Not Write in this Space

Keep one copy for your files

Name and title of person to contact regarding this report.

Telephone Number

Date questionnaire completed:

Return completed copies of questionnaire to:

Mr. Carl G. Beard, II
Project Director
Kanawha Valley Air Pollution Study
4108 MacCorkle Avenue, S.E.
Charleston, West Virginia 25304

INSTRUCTIONS

A. Prepare a separate form for each premise where fuel is used or products made.

B. Answer all questions. If certain questions are not applicable to your activity, please indicate NONE or NOT APPLICABLE.

C. Please return this report not later than 30 days after receipt to the Kanawha Valley Air Pollution Study.

I. Number of Production Employees at This Plant Premises (circle one only)

A. 10 or less C. 51-100 E. 501-1000
B. 11 - 50 D. 101-500 F. 1001-2000

II. Manufacturing Schedule

A. Days per week normally in operation
B. Days per year normally in operation
C. Number of shifts per day in normal operation

III. Process Operations

A. Principal Products (use 1964 data)

Products	Amount Produced - a (Designate units of production) - b	Specify months/year usually in production

a. If you do not want to disclose the amount produced, use the code indicated below to indicate range:

(A) Less than 1,000
(B) 1,001 to 10,000
(C) 10,001 to 100,000
(D) 100,001 to 200,000
(E) More than 200,000

b. Examples of units of production: tons/year, gallons/year, and/or trucks/year, pumps/year, etc.

IV. Combustible Waste Disposal

Waste material				
Type of waste[a] (See below)	Amount per year[b] (See below)	Method of disposal (See below)	Incinerator used capacity, lb/hr	Auxiliary fuel used[c]

Method of Disposal Code:

1 - Open burning in pit, dump, etc. on plant premise.
2 - Hauled to dump on plant premise, not burned.
3 - Picked up by private salvage or waste disposal company.
4 - Picked up by municipality.
5 - Burned in boiler or furnace.
6 - Incinerator, single chamber (one totally enclosed refractory-lined chamber in which both primary and secondary combustion take place.)
7 - Incinerator, multiple chamber (two or more refractory-lined chambers interconnected by gas passage parts or ducts and designed in such a manner as to provide for complete combustion of material.)
8 - Incinerator, rotary.
9 - Wigwam waste burner.
10 - Other

(Specify)

a - Example of type of waste - organic residues, tars, solvents, paper, garbage, etc.

b - Example of units - tons, pounds, gallons, cubic feet, cubic yards, etc.

c - Indicate whether auxiliary fuel is used in incinerators and pit burning.

V. Combustion Processes

A. Total fuel used for heat and power

Type Grade

Supplier: Captive External Both

If Coal: Ash %(dry basis) Sulfur %(dry basis)

If liquid: Sulfur % If gas: Sulfur %

Estimate of fuel consumed monthly: cubic feet

gallons tons

B. Total fuel used for process consumption

Type Grade

Supplier: Captive External Both

If Coal: Ash %(dry basis) Sulfur %(dry basis)

If liquid: Sulfur % If gas: Sulfur %

Estimate of fuel consumed monthly: cubic feet

gallons tons

C. Fly ash

Tons collected per month

Method of disposal

D. Boilers (for heat and power)

Boiler type (hand fired, stoker, pulverized, fuel, other)	Amount of fuel used, tons/day or equivalent	Stack height, ft.	Type of abatement equipment	Estimated efficiency[a] percent

[a] Efficiency data should be given in terms of weight and particle size, if available.

VI. Air Pollution Program

Do you have an established program of operational maintenance checks on your air pollution control devices? (check one)

Not applicable Yes No

Approximately what dollar amounts have you spent on air pollution control devices and operation during the past 15 years.

1. Equipment (total for 15 years).
2. Operations (total for 15 years).

APPENDIX C

Appendix C-1. Questionnaires

3. Solvents Used in Dry Cleaning Plants

1. Average monthly purchase of solvent, gallons per month*
(Total gallons of solvent purchases in 1964 divided by number of months dry cleaning plant operated).

	New	Reclaimed
Stoddard		
Safety Solvent 140		
Perchlorethylene		
Trichloroethylene		
Carbon Tetrachloride		
Other (trade or chemical name)		

2. Do you have and use solvent reclaiming equipment? Yes No

3. If you do not have solvent reclaiming equipment, what is the method of disposal for the used solvent? (Please check appropriate box)

   A. Shipment to solvent recovery plant

   B. Dumping

   C. Other, please describe method

   If Item B is checked, indicate site of solvent dumping

4. Average operating time for the dry cleaning equipment during 1964.
Hours per week A.M. P.M.
Days per week Mon. Tues. Wed. Thurs. Fri. Sat. Sun.
(Cross out days plant does not operate)

5. Estimated quantity of material dry cleaned, pounds per month:

6. Type of Plant Equipment. Describe:

7. Type of control equipment: Adsorption scrubbing
Direct flame incineration Condensation scrubbing
Catalytic incineration
None

*The following factors may be used to calculate gallons: (1) one drum contains 52.5 gallons. (2) one pound of perchlorethylene equals 0.074 gallon. (3) one pound of trichloroethylene equals 0.082 gallon.

APPENDIX C

Appendix C-1. Questionnaires

4. Commercial Fuel Use Questionnaire

Please return questionnaire to:

Mr. Carl G. Beard, II
Kanawha Valley Air Pollution Study
4108 MacCorkle Ave., S.E.
Charleston 1, West Virginia

Kanawha Valley Air Pollution Study

COMMERCIAL FUEL USE
QUESTIONNAIRE

Name and Address

Do Not Write in this Space

Keep one copy for your files

Name and Title of Person to Contact Regarding this Report.

Telephone Number

INSTRUCTIONS

A. Prepare a separate form for each premise where fuel is used.

B. Answer all questions. If certain questions are not applicable to your activity, please indicate NONE or NOT APPLICABLE.

C. Please return this report not later than 30 days after receipt to the Kanawha Valley Air Pollution Study.

1. Service or Building Classification (Circle one only)
    1. Bank
    2. Building - Public and Office
    3. Department Store
    4. Hospital
    5. Institution
    6. School
    7. Greenhouse & Flower Shop
    8. Hotel
    9. Laundry and/or Dry Cleaning Plant
    10. Other (Describe)
2. Fuel Consumption for Space Heating in 1964.

    Indicate more than one if appropriate.

    A. Principal types of fuel used:

    1. None 2. Coal 3. Oil 4. Gas 5. Other

    B. If COAL is principal fuel:

    1. How many short tons of COAL are consumed per year?

    ____

    2. Who is COAL supplier?

    Name

3. Percent Ash:
4. Percent Sulfur

C. If GAS is a principal fuel, how many 100 cubic feet of GAS are consumed per year?

D. If OIL is a principal fuel, how many gallons of OIL are consumed per year?
   1. Percent Sulfur:

E. If Oil is a principal fuel, check the grade of OIL.
   1. No. 1 Oil
   2. No. 2 Oil
   3. No. 3 Oil
   4. No. 4 Oil
   5. No. 5 Oil
   6. No. 6 Oil

3. Coal burning equipment and fly ash collecting equipment.
   A. Principal coal burning equipment (circle one only.)
      1. None
      2. Hand Fired
      3. Under Feed Stoker
      4. Chain Grate
      5. Traveling Grate
      6. Spreader Stoker with Ash Reinjection
      7. Spreader Stoker without Ash Reinjection.
      8. Pulverized Coal
      9. Other (Describe)

3. B. Fly ash collecting equipment associated with Item 3A above (Circle one only).
      1. None
      2. Settling Chamber/Baffles
      3. Simple Cyclone
      4. Multiple Cyclone
      5. Other Inertial Separator (Tubular, Cone, etc.)
      6. Water Sprays in Stack
      7. Scrubber
      8. Electrostatic Precipitator
      9. Other (Describe)

4. Combustible Waste Disposal (includes paper, rags, cartons, garbage, tar, paint, waste oil, etc.)
   A. How much combustible waste is disposed per year?
      1. None
      2. tons or other applicable units
   B. Principal methods of combustible waste disposal (Circle appropriate items)
      1. Not Applicable
      2. City Pickup
      3. Private Pickup
      4. Burn in Open Fire on Premise
      5. Burn in Boiler or Furnace
      6. Incinerate - single chamber
      7. Incinerate - multiple chamber
      8. Incinerate - Other (Describe)
      9. Other (Describe)
   C. If incinerator is circled in Section B above, what is its capacity in pounds per hour?
   D. Incineration Schedule:
      Weekly: Day(s).
      Daily: Hour(s).

5. Additional Remarks:

APPENDIX C

Appendix C-1. Questionnaires

5. Combustible Waste Disposal Questionnaire

Please return questionnaire to:

Mr. Carl G. Beard, II
Kanawha Valley Air Pollution Study
4108 MacCorkle Avenue, S.E.
Charleston, West Virginia

DO NOT WRITE IN THIS SPACE

Name and address (City Hall, etc.)

Name and Title of Person to Contact regarding this report.

Keep one copy for your files

Telephone Number

INSTRUCTIONS

A. Prepare a separate form for each disposal site.

B. Answer all questions. If certain questions are not applicable to your activity, please indicate NONE or NOT APPLICABLE.

C. Please return this report not later than 30 days after receipt to the Kanawha Valley Air Pollution Study.

Combustible Waste Disposal (includes paper, rags, cartons, garbage, tar, paint, waste oil, etc.)

1. How much combustible waste is disposed per year?

    A. None

    B. Tons or other applicable units.

2. Principal methods of combustible waste disposal (Circle appropriate items).

    A. Not applicable
    B. Incinerate - single chamber
    C. Incinerate - multiple chamber
    D. Incinerate - Other(Describe)
    E. Sanitary Landfill
    F. Open dump (no burning)
    G. Burn in open dump
    H. Other (Describe)

3. If incinerate is circled in Section 2 above,

    A. What is incinerator capacity in tons per hour?

    B. Incineration Schedule:

        Weekly: Day(s),
        Daily: Hour(s)

    C. Air pollution control equipment on incinerator, efficiency of control equipment and date that efficiencies were checked:

4. If sanitary landfill or open dump is circled in Section 2 above:

    A. What is the usable area for waste disposal (acres, etc.):

    B. What is estimated life of disposal site:

5. Brief description and location of site:

6. Brief description of combustible waste disposed of at this site (Commercial and Industrial wastes):

7. Are your disposal facilities utilized by other organizations, private and/or public? If yes, please list those using facilities.

8. Do you provide pickup service to areas outside your political jurisdiction? If yes, please list areas served:

9. Additional Remarks:

APPENDIX D. INSTRUMENTS

ANALYZER: SULFUR DIOXIDE (Davis Instruments)

The Davis Parts Per Million Analyzer operates on the principle of electrical conductance and ionization. The basic method of analysis differs little from the measurement made by Kohlrausch, Arrhenius and other early workers, in that determination of electrolytic conductivity is accomplished by measuring the ohmic resistance of a sample-water mixture passing over a pair of suitable electrodes. Errors due to polarization, i.e., the changes in the composition of the solution adjacent to the electrodes, are eliminated by employing alternating current.

The Davis analyzer is designed for continuous analysis. This is accomplished by the provision of a recirculating water supply system. All effluent from the special analyzing cell, after analysis, is continuously purged to the ion exchange reservoir, wherein mono-bed deionization takes place.

ANALYZER: NITROGEN DIOXIDE (Beckman Instruments)

The instrument is based upon the reaction of nitrogen dioxide with a reagent containing sulfanilic acid, N-(1 naphthyl)-ethylenediamine dihydrochloride, and acetic acid as reported by Saltzman. The colored reaction product absorbs light of 560 millimicrons wave length. Light absorbancy is measured in a ratio photometer and read on a special polentiometric recorder. Calibration is logarithmic. The mechanism of the reaction has been subject to some discussion. The nitrogen dioxide reacts with the sulfanic acid in the diazotization step, and the resulting diazo compound undergoes a coupling reaction with the N-(1 naphthyl)-ethylenediamine dihydrochloride.

OZONE METER (Mast Development Co.)

The sensing of ozone in the air sample is accomplished by the well known oxidation-reduction of potassium iodide which is contain d in the sensing solution. This reaction takes place on the cathode portion of the electrode support. In this region, any ozone in the air sample reacts with the sensing solution as follows:

$$O_3 + 2KI + H_2O \longrightarrow O_2 + I_2 + 2KOH$$

At the cathode, a thin layer of hydrogen gas is produced by a polarization current:

$$2e+2H^{+} \longrightarrow H_2$$

When the voltage is applied to the electrodes (about 0.25 volts), the hydrogen layer builds to its maximum and the polarization current ceases to flow.

When free iodine is produced by the reaction with ozone, it immediately reacts with the hydrogen as follows:

$$H_2I_2 \longrightarrow 2KI$$

The removal of the hydrogen from the cathode causes a re-polarization current of two electrons to flow in the external circuit, re-establishing equilibrium. Thus, for each ozone molecule reacting in the sensor, two electrons flow through the external circuit. Hence, the rate of electron flow, or current, is directly proportional to mass per unit time of ozone entering the sensor.

FLAME IONIZATION DETECTOR: HYDROCARBON

(Perkin-Elmer Corporation and Beckman Instruments)

The organic concentration of the sample is detected by an internal hydrogen flame ionization detector. Since different classes or organic compounds have different detector responses, the meter indication for a given sample must be interpreted upon the basis of instrument calibration with an appropriate test gas.

The detector assembly used in the Model 223, operates with pressure-regulated sources of sample, hydrogen, and air. Hydrogen and sample are combined and the resulting stream is banned at a jet in a surrounding atmosphere of air.

The Model 223 can be considered essentially a carbon atom counter, since its output is proportional to the total carbon content of the sample. For example, equal molar concentrations of propane and hexane (C_3H_8 and C_6H_{14}) give relative responses of 1 and 2, since the total number of carbon atoms in the hexane sample is twice that in the propane. The detector is sensitive only to compounds in which carbon is bonded to hydrogen, halogens or other carbon atoms. Carbon monoxide, carbon dioxide, water, ammonia, and the oxides of nitrogen are not detectable.

INFRARED ANALYZERS: CARBON MONOXIDE AND CARBON DIOXIDE

(Beckman Instruments)

The infrared analysis for both carbon monoxide and carbon dioxide is based on the same principles. Flow through the sample cell brings gas or liquid which is to be monitored. The instrument is sensitized to detect this sample, and when no sample is present in the sample cell, the instrument reads zero. In operation, infrared radiation is emitted by the two sources and chopped by a light chopper. The chopped beams pass through the sample cell (filled with sample) and the reference cell (filled with reference material). Any monitored sample absorbs energy from the source radiation so that material in the sample cell absorbs greater energy than material in the reference cell. Thus, the beams which emerge from the cells to the two compartments of the detector are no longer equal in energy. This causes movement of a diaphragm-condenser between the two compartments of the detector. An electrical signal is produced across the condenser, which is proportional to the amount of monitored sample in the sample cell. This electrical signal goes to the amplifier where the quanitity of sample is expressed as an electrical voltage. This voltage goes to a meter which gives readings corresponding to sample concentrations. The signal also may be relayed to a recorder for permanent record.

APPENDIX E. DESCRIPTION OF FIXED SAMPLING STATIONS

Table E-1. DESCRIPTION OF FIXED SAMPLING STATIONS

Station location	Site description	Area classification,[1] ½ mile-1 mile-2 miles	Sampling equipment[2]
Falls View National Guard Armory, U.S. Rt. 60	Flat roof, height 25 ft.	1 - 1 - 1,3	a,b,c,d
Montgomery Heights Residence (Trailer), State Rt. 61	Utility pole, height 10 ft.	1,3 - 1,3 - 1,3	c,d
Kimberly Kimberly Grade School	Flat roof, height 15 ft.	1 - 1 - 1,3	c,d
Boomer St. Anthony's Parish Hall U.S. Rt. 60	Flat roof, height 30 ft.	1 - 1 - 1,2,3	c,d
Smithers Oakwood Grade School 218 Kanawha Avenue	Parapet roof, height 35 ft.	1,2 - 1,2,3 - 1,2,3	a,b,c,d
Montgomery Engineering Building West Virginia Institute of Technology, Jackson Street	Parapet roof, height 25 ft.	1,2,3 - 1,2,3 - 1,2,3	a,b,c,d,e
Cedar Grove Cedar Grove High School, Railway St.	Flat roof, height 12 ft.	1,2 - 1,2,3 - 1,2,3	a,b,c,d,e
Chelyan Slater Motor Company, State Rt. 61	Curved roof, height 20 ft.	1,2 - 1,2,3 - 1,2,3	c,d
Belle U. S. Post Office 814 E. du Pont Avenue	Flat roof, height 15 ft.	1,2 - 1,2,3 - 1,2,3	c,d
Chesapeake Chesapeake Elementary School 12404 MacCorkle Ave., S.E.	Parapet roof, height 20 ft.	1,2 - 1,2,3 - 1,2,3	c,d
Marmet Marmet Elementary School 408 94th Street	Parapet roof, height 25 ft.	1,2,3 - 1,2,3 - 1,2,3	a,b,c,d,e

Table E-1 (continued). DESCRIPTION OF FIXED SAMPLING STATIONS

Station location	Site description	Area classification,[1] ½ mile-1 mile-2 miles	Sampling equipment[2]
South Malden Zims Supply Company 7300 MacCorkle Ave., S.E.	Flat roof, height 22 ft.	1,2 - 1,2,3 - 1,2,3	c,d
Kanawha City Horace Mann Jr. High School 43rd & MacCorkle Avenue, S.E.	Parapet roof, height 25 ft.	1,2 - 1,2 - 1,2,3	a,b,c,d,e
East Charleston State Office Building #3 1800 Washington St., E.	Parapet roof, height 70 ft.	1,2 - 1,2,3 - 1,2,3	c,d
Charleston Federal Building, 500 Quarrier St.,E.	Flat roof, height 60 ft.	1,2 - 1,2,3 - 1,2,3	a,b,c,d,e
Crede Elk River - Garage owned by Mr. Paisley	Sloping roof, height 10 ft.	1 - 1,2 - 1,2,3	c,d
West Charleston Glenwood Elementary School Glenwood Avenue	Parapet roof, height 35 ft.	1,2 - 1,2,3 - 1,2,3	a,b,c,d,e
North Charleston, E. North Charleston Fire Station 504 25th Street	Parapet roof, height 35 ft.	1,2,3 - 1,2,3 - 1,2,3	c,d
North Charleston, W. Pump Station (Sewage), North Charleston Recreation Center 2009 7th Avenue, W.	Flat roof, height 20 ft.	1,2,3 - 1,2,3 - 1,2,3	a,b,c,d,e
South Charleston, E. South Charleston High School C Street & 3rd Avenue	Flat roof, height 35 ft.	1,2,3 - 1,2,3 - 1,2,3	a,b,c,d,e
South Charleston, W. State Police Barracks, Company B	Flat roof, height 15 ft.	1,2 - 1,2,3 - 1,2,3	c,d

Table E-1 (continued). DESCRIPTION OF FIXED SAMPLING STATIONS

Station location	Site description	Area classification,[1] ½ mile-1 mile-2 miles	Sampling equipment[2]
Dunbar Ford Elementary School, 137 6th St.	Flat roof, height 25 ft.	1,2 - 1,2 - 1,2,3	a,b,c,d,e
Institute Student Union Building West Virginia State College	Flat roof, height 25 ft.	1,2,3 - 1,2,3 - 1,2,3	c,d
St. Albans Albans Elementary School 2030 Harrison Avenue	Flat roof, height 12 ft.	1,2 - 1,2,3 - 1,2,3	a,b,c,d,e
Nitro Nitro Jr. High School Park Avenue & 15th Avenue	Flat roof, height 20 ft.	1,2,3 - 1,2,3 - 1,2,3	a,b,c,d,e
West of St. Albans Anne Bailey Elementary School State Rt. 17	Flat roof, height 12 ft.	1 - 1,2 - 1,2,3	c,d
West of Nitro Craft's Farm, State Rt. 17 1/4 mile West of Interstate Bridge	Platform, ground level	4 - 1,3 - 1,2,3	a,b,c,d,e

[1] Area classification

1. Residential
2. Commercial
3. Industrial
4. Rural

[2] Sampling equipment

a. High volume sampler
b. AISI tape sampler
c. Dustfall
d. Sulfation
e. Materials deterioration - metals and nylon